



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : C12N 9/00	A2-	(11) International Publication Number: WO 00/60059 (43) International Publication Date: 12 October 2000 (12.10.00)
<p>(21) International Application Number: PCT/DK00/00148</p> <p>(22) International Filing Date: 28 March 2000 (28.03.00)</p> <p>(30) Priority Data: PA 1999 00437 30 March 1999 (30.03.99) DK</p> <p>(71) Applicant: NOVO NORDISK A/S [DK/DK]; Novo Allé, DK-2880 Bagsværd (DK).</p> <p>(72) Inventors: ANDERSEN, Carsten; Højeloft Vænge 162, DK-3500 Værløse (DK). JØRGENSEN, Christel, Thea; Livjærgergade 41, 4.th., DK-2100 Copenhagen Ø (DK). BISGÅRD-FRANTZEN, Henrik; Elmevænget 8B, DK-2880 Bagsværd (DK). SVENDSEN, Allan; Bakkeledet 28, DK-3460 Birkerød (DK). KJÆRULFF, Søren; Kongsdalsvej 47, DK-2720 Vanløse (DK).</p>		<p>(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>Without international search report and to be republished upon receipt of that report.</i></p>
<p>(54) Title: ALPHA-AMYLASE VARIANTS</p> <p>(57) Abstract</p> <p>The invention relates to a variant of a parent Termamyl-like alpha-amylase, which variant exhibits altered properties, in particular reduced capability of cleaving a substrate close to the branching point, and improved substrate specificity and/or improved specific activity relative to the parent alpha-amylase.</p>		

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Alpha-AMYLASE VARIANTS

FIELD OF THE INVENTION

The present invention relates, *inter alia*, to novel variants
5 of parent Termamyl-like alpha-amylases, notably variants
exhibiting altered properties, in particular altered cleavage
pattern (relative to the parent) which are advantageous with
respect to applications of the variants in, in particular,
industrial starch processing (e.g., starch liquefaction or
10 saccharification).

BACKGROUND OF THE INVENTION

Alpha-Amylases (alpha-1,4-glucan-4-glucanohydrolases, EC
3.2.1.1) constitute a group of enzymes which catalyze hydrolysis
15 of starch and other linear and branched 1,4-glucosidic oligo-
and polysaccharides.

There is a very extensive body of patent and scientific
literature relating to this industrially very important class of
enzymes. A number of alpha-amylase such as Termamyl-like
20 alpha-amylases variants are known from, e.g., WO 90/11352, WO
95/10603, WO 95/26397, WO 96/23873, WO 96/23874 and WO 97/41213.

Among recent disclosure relating to alpha-amylases, WO
96/23874 provides three-dimensional, X-ray crystal structural
data for a Termamyl-like alpha-amylase, referred to as BA2,
25 which consists of the 300 N-terminal amino acid residues of the
B. amyloliquefaciens alpha-amylase comprising the amino acid
sequence shown in SEQ ID NO: 6 herein and amino acids 301-483 of
the C-terminal end of the *B. licheniformis* alpha-amylase
comprising the amino acid sequence shown in SEQ ID NO: 4 herein
30 (the latter being available commercially under the tradename
Termamyl™), and which is thus closely related to the
industrially important *Bacillus* alpha-amylases (which in the
present context are embraced within the meaning of the term
"Termamyl-like alpha-amylases", and which include, *inter alia*,
35 the *B. licheniformis*, *B. amyloliquefaciens* and *B.*
stearothermophilus alpha-amylases). WO 96/23874 further
describes methodology for designing, on the basis of an analysis

of the structure of a parent Termamyl-like alpha-amylase, variants of the parent Termamyl-like alpha-amylase which exhibit altered properties relative to the parent.

WO 96/23874 and WO 97/41213 (Novo Nordisk) discloses
5 Termamyl-like alpha-amylase variants with an altered cleavage pattern containing mutations in the amino acid residues V54, D53, Y56, Q333, G57 and A52 of the sequence shown in SEQ ID NO: 4 herein.

10 BRIEF DISCLOSURE OF THE INVENTION

The present invention relates to novel alpha-amylolytic variants (mutants) of a Termamyl-like alpha-amylase, in particular variants exhibiting altered cleavage pattern (relative to the parent), which are advantageous in connection
15 with the industrial processing of starch (starch liquefaction, saccharification and the like).

The inventors have surprisingly found variants with altered properties, in particular altered cleavage pattern which have improved reduced capability of cleaving an substrate close to
20 the branching point, and further have improved substrate specificity and/or improved specific activity, in comparison to the WO 96/23874 and WO 97/41213 (Novo Nordisk) disclosed Termamyl-like alpha-amylase variants with an altered cleavage pattern containing mutations in the amino acid residues V54,
25 D53, Y56, Q333, G57 and A52 of the sequence shown in SEQ ID NO: 4 herein.

The invention further relates to DNA constructs encoding variants of the invention, to composition comprising variants of the invention, to methods for preparing variants of the
30 invention, and to the use of variants and compositions of the invention, alone or in combination with other alpha-amylolytic enzymes, in various industrial processes, e.g., starch liquefaction, and in detergent compositions, such as laundry, dish washing and hard surface cleaning compositions; ethanol
35 production, such as fuel, drinking and industrial ethanol production; desizing of textiles, fabrics or garments etc.

Nomenclature

In the present description and claims, the conventional one-letter and three-letter codes for amino acid residues are used.

For ease of reference, alpha-amylase variants of the invention are described by use of the following nomenclature:

Original amino acid(s):position(s):substituted amino acid(s)

According to this nomenclature, for instance the substitution of alanine for asparagine in position 30 is shown as:

Ala30Asn or A30N

a deletion of alanine in the same position is shown as:

Ala30* or A30*

and insertion of an additional amino acid residue, such as lysine, is shown as:

*30aLys or *30aK

A deletion of a consecutive stretch of amino acid residues, such as amino acid residues 30-33, is indicated as (30-33)* or Δ (A30-N33) or delta(A30-N33).

Where a specific alpha-amylase contains a "deletion" in comparison with other alpha-amylases and an insertion is made in such a position this is indicated as:

*36aAsp or *36aD

for insertion of an aspartic acid in position 36

Multiple mutations are separated by plus signs, i.e.:

Ala30Asp + Glu34Ser or A30N+E34S

representing mutations in positions 30 and 34 substituting alanine and glutamic acid for asparagine and serine, respectively. Multiple mutations may also be separated as follows, i.e., meaning the same as the plus sign:

Ala30Asp/Glu34Ser or A30N/E34S

When one or more alternative amino acid residues may be inserted in a given position it is indicated as

A30N,E or

A30N or A30E

Furthermore, when a position suitable for modification is identified herein without any specific modification being suggested, or A30X, it is to be understood that any amino acid

residue may be substituted for the amino acid residue present in the position. Thus, for instance, when a modification of an alanine in position 30 is mentioned, but not specified, or specified as "X", it is to be understood that the alanine may be
5 deleted or substituted for any other amino acid, i.e., any one of: R,N,D,C,Q,E,G,H,I,L,K,M,F,P,S,T,W,Y,V.

DETAILED DISCLOSURE OF THE INVENTION

The Termamyl-like alpha-amylase

10 It is well known that a number of alpha-amylases produced by *Bacillus* spp. are highly homologous on the amino acid level. For instance, the *B. licheniformis* alpha-amylase comprising the amino acid sequence shown in SEQ ID NO: 4 (commercially available as Termamyl™) has been found to be about 89%
15 homologous with the *B. amyloliquefaciens* alpha-amylase comprising the amino acid sequence shown in SEQ ID NO: 6 and about 79% homologous with the *B. stearootherophilus* alpha-amylase comprising the amino acid sequence shown in SEQ ID NO: 8. Further homologous alpha-amylases include an alpha-amylase
20 derived from a strain of the *Bacillus* sp. NCIB 12289, NCIB 12512, NCIB 12513 or DSM 9375, all of which are described in detail in WO 95/26397, and the #707 alpha-amylase described by Tsukamoto et al., Biochemical and Biophysical Research Communications, 151 (1988), pp. 25-31.

25 Still further homologous alpha-amylases include the alpha-amylase produced by the *B. licheniformis* strain described in EP 0252666 (ATCC 27811), and the alpha-amylases identified in WO 91/00353 and WO 94/18314. Other commercial Termamyl-like *B. licheniformis* alpha-amylases are Optitherm™ and Takatherm™
30 (available from Solvay), Maxamyl™ (available from Gist-brocades/Genencor), Spezym AA™ and Spezyme Delta AA™ (available from Genencor), and Keistase™ (available from Daiwa).

Because of the substantial homology found between these alpha-amylases, they are considered to belong to the same class
35 of alpha-amylases, namely the class of "Termamyl-like alpha-amylases".

Accordingly, in the present context, the term "Termamyl-like alpha-amylase" is intended to indicate an alpha-amylase, which at the amino acid level exhibits a substantial homology to Termamyl™, i.e., the *B. licheniformis* alpha-amylase having the amino acid sequence shown in SEQ ID NO: 4 herein. In other words, a Termamyl-like alpha-amylase is an alpha-amylase, which has the amino acid sequence shown in SEQ ID NO: 2, 4, 6, or 8 herein, and the amino acid sequence shown in SEQ ID NO: 1 or 2 of WO 95/26397 or in Tsukamoto et al., 1988, or i) which displays at least 60%, preferred at least 70%, more preferred at least 75%, even more preferred at least 80%, especially at least 85%, especially preferred at least 90%, even especially more preferred at least 95% homology, more preferred at least 97%, more preferred at least 99% with at least one of said amino acid sequences and/or ii) displays immunological cross-reactivity with an antibody raised against at least one of said alpha-amylases, and/or iii) is encoded by a DNA sequence which hybridises to the DNA sequences encoding the above-specified alpha-amylases which are apparent from SEQ ID NOS: 1, 3, 5 and 7 of the present application and SEQ ID NOS: 4 and 5 of WO 95/26397, respectively.

In connection with property i), the "homology" may be determined by use of any conventional algorithm, preferably by use of the GAP programme from the GCG package version 7.3 (June 1993) using default values for GAP penalties, which is a GAP creation penalty of 3.0 and GAP extension penalty of 0.1, (Genetic Computer Group (1991) Programme Manual for the GCG Package, version 7, 575 Science Drive, Madison, Wisconsin, USA 53711).

A structural alignment between Termamyl and a Termamyl-like alpha-amylase may be used to identify equivalent/corresponding positions in other Termamyl-like alpha-amylases. One method of obtaining said structural alignment is to use the Pile Up programme from the GCG package using default values of gap penalties, i.e., a gap creation penalty of 3.0 and gap extension penalty of 0.1. Other structural alignment methods include the hydrophobic cluster analysis (Gaboriaud et al.,

(1987), FEBS LETTERS 224, pp. 149-155) and reverse threading (Huber, T ; Torda, AE, PROTEIN SCIENCE Vol. 7, No. 1 pp. 142-149 (1998). Property ii) of the alpha-amylase, i.e., the immunological cross reactivity, may be assayed using an antibody
5 raised against, or reactive with, at least one epitope of the relevant Termamyl-like alpha-amylase. The antibody, which may either be monoclonal or polyclonal, may be produced by methods known in the art, e.g., as described by Hudson et al., Practical Immunology, Third edition (1989), Blackwell Scientific
10 Publications. The immunological cross-reactivity may be determined using assays known in the art, examples of which are Western Blotting or radial immunodiffusion assay, e.g., as described by Hudson et al., 1989. In this respect, immunological cross-reactivity between the alpha-amylases having the amino acid
15 sequences SEQ ID NOS: 2, 4, 6, or 8, respectively, have been found.

The oligonucleotide probe used in the characterization of the Termamyl-like alpha-amylase in accordance with property iii) above may suitably be prepared on the basis of the full or
20 partial nucleotide or amino acid sequence of the alpha-amylase in question.

Suitable conditions for testing hybridization involve presoaking in 5xSSC and prehybridizing for 1 hour at ~40°C in a solution of 20% formamide, 5xDenhardt's solution, 50mM sodium
25 phosphate, pH 6.8, and 50mg of denatured sonicated calf thymus DNA, followed by hybridization in the same solution supplemented with 100mM ATP for 18 hours at ~40°C, followed by three times washing of the filter in 2xSSC, 0.2% SDS at 40°C for 30
minutes (low stringency), preferred at 50°C (medium
30 stringency), more preferably at 65°C (high stringency), even more preferably at ~75°C (very high stringency). More details about the hybridization method can be found in Sambrook et al., Molecular Cloning: A Laboratory Manual, 2nd Ed., Cold Spring Harbor, 1989.

35 In the present context, "derived from" is intended not only to indicate an alpha-amylase produced or producible by a strain of the organism in question, but also an alpha-amylase encoded

by a DNA sequence isolated from such strain and produced in a host organism transformed with said DNA sequence. Finally, the term is intended to indicate an alpha-amylase, which is encoded by a DNA sequence of synthetic and/or cDNA origin and which has the identifying characteristics of the alpha-amylase in question. The term is also intended to indicate that the parent alpha-amylase may be a variant of a naturally occurring alpha-amylase, i.e. a variant, which is the result of a modification (insertion, substitution, deletion) of one or more amino acid residues of the naturally occurring alpha-amylase.

Parent hybrid alpha-amylases

The parent alpha-amylase may be a hybrid alpha-amylase, i.e., an alpha-amylase, which comprises a combination of partial amino acid sequences derived from at least two alpha-amylases.

The parent hybrid alpha-amylase may be one, which on the basis of amino acid homology and/or immunological cross-reactivity and/or DNA hybridization (as defined above) can be determined to belong to the Termamyl-like alpha-amylase family. In this case, the hybrid alpha-amylase is typically composed of at least one part of a Termamyl-like alpha-amylase and part(s) of one or more other alpha-amylases selected from Termamyl-like alpha-amylases or non-Termamyl-like alpha-amylases of microbial (bacterial or fungal) and/or mammalian origin.

Thus, the parent hybrid alpha-amylase may comprise a combination of partial amino acid sequences deriving from at least two Termamyl-like alpha-amylases, or from at least one Termamyl-like and at least one non-Termamyl-like bacterial alpha-amylase, or from at least one Termamyl-like and at least one fungal alpha-amylase. The Termamyl-like alpha-amylase from which a partial amino acid sequence derives may, e.g., be any of those specific Termamyl-like alpha-amylases referred to herein.

For instance, the parent alpha-amylase may comprise a C-terminal part of an alpha-amylase derived from a strain of *B. licheniformis*, and a N-terminal part of an alpha-amylase derived from a strain of *B. amyloliquefaciens* or from a strain of *B. stearothermophilus*. For instance, the parent alpha-amylase may

comprise at least 430 amino acid residues of the C-terminal part of the *B. licheniformis* alpha-amylase, and may, e.g., comprise a) an amino acid segment corresponding to the 37 N-terminal amino acid residues of the *B. amyloliquefaciens* alpha-amylase having the amino acid sequence shown in SEQ ID NO: 6 and an amino acid segment corresponding to the 445 C-terminal amino acid residues of the *B. licheniformis* alpha-amylase having the amino acid sequence shown in SEQ ID NO: 4, or b) an amino acid segment corresponding to the 68 N-terminal amino acid residues of the *B. stearothermophilus* alpha-amylase having the amino acid sequence shown in SEQ ID NO: 8 and an amino acid segment corresponding to the 415 C-terminal amino acid residues of the *B. licheniformis* alpha-amylase having the amino acid sequence shown in SEQ ID NO: 4.

In a preferred embodiment the parent Termamyl-like alpha-amylase is a hybrid Termamyl-like alpha-amylase identical to the *Bacillus licheniformis* alpha-amylase shown in SEQ ID NO: 4, except that the N-terminal 35 amino acid residues (of the mature protein) is replaced with the N-terminal 33 amino acid residues of the mature protein of the *Bacillus amyloliquefaciens* alpha-amylase (BAN) shown in SEQ ID NO: 6. Said hybrid may further have the following mutations: H156Y+A181T+N190F+A209V+Q264S (using the numbering in SEQ ID NO: 4) referred to as LE174.

Another preferred parent hybrid alpha-amylase is LE429 shown in SEQ ID NO: 2.

The non-Termamyl-like alpha-amylase may, e.g., be a fungal alpha-amylase, a mammalian or a plant alpha-amylase or a bacterial alpha-amylase (different from a Termamyl-like alpha-amylase). Specific examples of such alpha-amylases include the *Aspergillus oryzae* TAKA alpha-amylase, the *A. niger* acid alpha-amylase, the *Bacillus subtilis* alpha-amylase, the porcine pancreatic alpha-amylase and a barley alpha-amylase. All of these alpha-amylases have elucidated structures, which are markedly different from the structure of a typical Termamyl-like alpha-amylase as referred to herein.

The fungal alpha-amylases mentioned above, i.e., derived from *A. niger* and *A. oryzae*, are highly homologous on the amino

acid level and generally considered to belong to the same family of alpha-amylases. The fungal alpha-amylase derived from *Aspergillus oryzae* is commercially available under the tradename Fungamyl™.

5 Furthermore, when a particular variant of a Termamyl-like alpha-amylase (variant of the invention) is referred to - in a conventional manner - by reference to modification (e.g., deletion or substitution) of specific amino acid residues in the amino acid sequence of a specific Termamyl-like alpha-amylase,
10 it is to be understood that variants of another Termamyl-like alpha-amylase modified in the equivalent position(s) (as determined from the best possible amino acid sequence alignment between the respective amino acid sequences) are encompassed thereby.

15 A preferred embodiment of a variant of the invention is one derived from a *B. licheniformis* alpha-amylase (as parent Termamyl-like alpha-amylase), e.g., one of those referred to above, such as the *B. licheniformis* alpha-amylase having the amino acid sequence shown in SEQ ID NO: 4.

20

Construction of variants of the invention

The construction of the variant of interest may be accomplished by cultivating a microorganism comprising a DNA sequence encoding the variant under conditions which are
25 conducive for producing the variant. The variant may then subsequently be recovered from the resulting culture broth. This is described in detail further below.

Altered properties

30 The following discusses the relationship between mutations, which may be present in variants of the invention, and desirable alterations in properties (relative to those of a parent Termamyl-like alpha-amylase), which may result there from.

In the first aspect the invention relates to a variant of
35 a parent Termamyl-like alpha-amylase, comprising an alteration at one or more positions selected from the group of:

W13, G48, T49, S50, Q51, A52, D53, V54, G57, G107, G108, A111,

S168, M197, wherein (a) the alteration(s) are independently

(i) an insertion of an amino acid downstream of the amino acid which occupies the position,

(ii) a deletion of the amino acid which occupies the position, or

(iii) a substitution of the amino acid which occupies the position with a different amino acid,

(b) the variant has alpha-amylase activity and (c) each position corresponds to a position of the amino acid sequence of the parent Termamyl-like alpha-amylase having the amino acid sequence of SEQ ID NO: 4.

In a preferred embodiment the above variants of the invention comprise a mutation in a position corresponding to at least one of the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

V54N, A52S, A52S+V54N, T49L, T49+G107A, A52S+V54N+T49L+G107A,

A52S+V54N+T49L, G107A, Q51R, Q51R+A52S, A52N; or

T49F+G107A, T49V+G107A, T49D+G107A, T49Y+G107A, T49S+G107A,

T49N+G107A, T49I+G107A, T49L+A52S+G107A, T49L+A52T+G107A,

T49L+A52F+G107A, T49L+A52L+G107A, T49L+A52I+G107A,

T49L+A52V+G107A; or

T49V, T49I, T49D, T49N, T49S, T49Y, T49F, T49W, T49M, T49E,

T49Q, T49K, T49R, A52T, A52L, A52I, A52V, A52M, A52F, A52Y,

A52W, V54M, G107V, G07I, G107L, G107C.

In a preferred embodiment a variant of the invention comprises at least one mutation in a position corresponding to the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

W13F, L, I, V, Y, A;

G48A, V, S, T, I, L;

*48aD or *48aY (i.e., insertion of D or Y);

T49X;

*49aX (i.e., insertion of any possible amino acid residue)

S50X, in particular D, Y, L, T, V, I;

Q51R, K;

A52X, in particular A52S, N, T, F, L, I, V;

D53E, Q, Y, I, N, S, T, V, L;

V54X, in particular V54I,N,W,Y,F,L;
G57S,A,V,L,I,F,Y,T;
G107X, in particular G107A,V,S,T,I,L,C;
G108X, in particular G108A,V,S,T,I,L;
5 A111V,I,L;
S168Y;
M197X, in particular Y,F,L,I,T,A,G.

In a preferred embodiment a variant of the invention comprises the following mutations corresponding to the following
10 mutations in the amino acid sequence shown in SEQ ID NO: 4:
T49X+A52X+V54N/I/L/Y/F/W+G107A, and may further comprise G108A.

In a preferred embodiment a variant of the invention comprises at least one mutation corresponding to the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

15 T49L+G107A;
T49I+G107A;
T49L+G107A+V54I;
T49I+G107A+V54I;
A52S+V54N+T49L+G107A;
20 A52S+V54I+T49L+G107A;
A52S+T49L+G107A;
A52T+T49L+G107A;
A52S+V54N+T49I+G107A;
A52S+V54I+T49I+G107A;
25 A52S+T49I+G107A;
T49L+G108A;
T49I+G108A;
T49L+G108A+V54I;
T49I+G108A+V54I.

30 All of the above-mentioned variants of the invention have altered properties (meaning increased or decreased properties), in particular at least one of the following properties relative to the parent alpha-amylase: reduced ability to cleave a substrate close to the branching point, improved substrate
35 specificity and/or improved specific activity, altered substrate binding, altered thermal stability, altered pH/activity profile, altered pH/stability profile, altered stability towards

oxidation, altered Ca^{2+} dependency.

5 Stability

 In the context of the present invention, mutations (including amino acid substitutions and/or deletions) of importance with respect to achieving altered stability, in particular improved stability (i.e., higher or lower), at
10 especially low pH (i.e., pH 4-6) include any of the mutations listed in the in "Altered properties" section, above and the variants mentioned right below.

 The following variants: Q360A,K; N102A, N326A,L, N190G, N190K; Y262A,K,E (using the BAN, i.e., SEQ ID N: 6, numbering)
15 were also tested for pH stability. A preferred parent alpha-amylase may be BA2 described above. The pH stability was determined as described in the "Materials & Methods" section.

20 Ca^{2+} stability

 Altered Ca^{2+} stability means the stability of the enzyme under Ca^{2+} depletion has been improved, i.e., higher or lower stability. In the context of the present invention, mutations (including amino acid substitutions) of importance with respect
25 to achieving altered Ca^{2+} stability, in particular improved Ca^{2+} stability, i.e., higher or lower stability, at especially low pH (i.e., pH 4-6) include any of the mutations listed in the in "Altered properties" section above.

30 Specific activity

 In a further aspect of the present invention, important mutations with respect to obtaining variants exhibiting altered specific activity, in particular increased or decreased specific activity, especially at temperatures from 60-100°C, preferably
35 70-95°C, especially 80-90°C, include any of the mutations listed in the in "Altered properties" section above.

 The specific activity of LE174 and LE429 was determined to

16,000 NU/mg using the Phadebas[®] assay described in the "Materials and Methods" section.

Altered cleavage pattern

5 In the starch liquefaction process it is desirable to use an alpha-amylase, which is capable of degrading the starch molecules into long, branched oligosaccharides, rather than an alpha-amylase, which gives rise to formation of shorter, branched oligosaccharides (like conventional Termamyl-like
10 alpha-amylases). Short, branched oligosaccharides (panose precursors) are not hydrolyzed satisfactorily by pullulanases, which are used after alpha-amylase treatment in the liquefaction process, or simultaneously with a saccharifying amyloglucosidase (glucoamylase), or before adding a saccharifying
15 amyloglucosidase (glucoamylase). Thus, in the presence of panose precursors, the product mixture present after the glucoamylase treatment contains a significant proportion of short, branched, so-called limit-dextrin, viz. the trisaccharide panose. The presence of panose lowers the saccharification yield significantly and is thus undesirable.
20

It has been reported previously (US patent 5,234,823) that, when saccharifying with glucoamylase and pullulanase, the presence of residual alpha-amylase activity arising from the liquefaction process, can lead to lower yields of glucose,
25 if the alpha-amylase is not inactivated before the saccharification stage. This inactivation can be typically carried out by adjusting the pH to below 4.7 at 95°C, before lowering the temperature to 60°C for saccharification.

The reason for this negative effect on glucose yield is not fully understood, but it is assumed that the liquefying
30 alpha-amylase (for example Termamyl 120 L from *B.licheniformis*) generates "limit dextrins" (which are poor substrates for pullulanase), by hydrolysing 1,4-alpha-glucosidic linkages close to and on both sides of the
35 branching points in amylopectin. Hydrolysis of these limit dextrins by glucoamylase leads to a build up of the trisaccharide panose, which is only slowly hydrolysed by

glucoamylase.

The development of a thermostable alpha-amylase, which does not suffer from this disadvantage, would be a significant improvement, as no separate inactivation step would be required.

Thus, the aim of the present invention is to arrive at a mutant alpha-amylase having appropriately modified starch-degradation characteristics but retaining the thermostability of the parent Termamyl-like alpha-amylase.

Accordingly, the invention relates to a variant of a Termamyl-like alpha-amylase, which has an improved reduced ability to cleave a substrate close to the branching point, and further has improved substrate specificity and/or improved specific activity.

Of particular interest is a variant, which cleaves an amylopectin substrate, from the reducing end, more than one glucose unit from the branching point, preferably more than two or three glucose units from the branching point, i.e., at a further distance from the branching point than that obtained by use of a wild type *B. licheniformis* alpha-amylase.

It may be mentioned here that according to WO 96/23874, variants comprising at least one of the following mutations are expected to prevent cleavage close to the branching point:

V54L, I, F, Y, W, R, K, H, E, Q;

D53L, I, F, Y, W;

Y56W;

Q333W;

G57, all possible amino acid residues;

A52, amino acid residues larger than A, e.g., A52W, Y, L, F, I.

Mutations of particular interest in relation to obtaining variants according to the invention having an improved reduced ability to cleave a substrate close to the branching point, and further has improved substrate specificity and/or improved specific activity include mutations at the following positions in *B. licheniformis* alpha-amylase, SEQ ID NO: 4:

H156, A181, N190, A209, Q264 and I201.

It should be emphasised that not only the Termamyl-like

alpha-amylases mentioned specifically below may be used. Also other commercial Termamyl-like alpha-amylases can be used. An unexhaustive list of such alpha-amylases is the following:

Alpha-amylases produced by the *B. licheniformis* strain described
5 in EP 0252666 (ATCC 27811), and the alpha-amylases identified in
WO 91/00353 and WO 94/18314. Other commercial Termamyl-like *B. licheniformis* alpha-amylases are Optitherm™ and Takatherm™ (available from Solvay), Maxamyl™ (available from Gist-brocades/Genencor), Spezym AA™ Spezyme Delta AA™ (available
10 from Genencor), and Keistase™ (available from Daiwa).

All Termamyl-like alpha-amylase may suitably be used as backbone for preparing variants of the invention.

In a preferred embodiment of the invention the parent Termamyl-like alpha-amylase is a hybrid alpha-amylase of SEQ ID
15 NO: 4 and SEQ ID NO: 6. Specifically, the parent hybrid Termamyl-like alpha-amylase may be a hybrid alpha-amylase comprising the 445 C-terminal amino acid residues of the *B. licheniformis* alpha-amylase shown in SEQ ID NO: 4 and the 37 N-terminal amino acid residues of the mature alpha-amylase derived
20 from *B. amyloliquefaciens* shown in SEQ ID NO: 6, which may suitably further have the following mutations: H156Y+A181T+N190F+A209V+Q264S (using the numbering in SEQ ID NO: 4). This hybrid is referred to as LE174. The LE174 hybrid may be combined with a further mutation I201F to form a parent hybrid
25 Termamyl-like alpha-amylase having the following mutations H156Y+A181T+N190F+A209V+Q264S+I201F (using SEQ ID NO: 4 for the numbering). This hybrid variant is shown in SEQ ID NO: 2 and is used in the examples below, and is referred to as LE429.

Also, LE174 or LE429 (SEQ ID NO: 2) or *B. licheniformis*
30 alpha-amylase shown in SEQ ID NO: 4 comprising one or more of the following mutations may be used as backbone (using SEQ ID NO: 4 for the numbering of the mutations):

E119C;
S130C;
35 D124C;
R127C;

A52all possible amino acid residues;
S85all possible amino acid residues;
N96all possible amino acid residues;
V129all possible amino acid residues;
5 A269all possible amino acid residues;
A378all possible amino acid residues;
S148all possible amino acid residues, in particular S148N;
E211all possible amino acid residues, in particular E211Q;
N188all possible amino acid residues, in particular N188S, N188P
10 M197all possible amino acid residues, in particular M197T,
M197A, M197G, M197I, M197L, M197Y, M197F, M197I;
W138all possible amino acid residues, in particular W138Y;
D207all possible amino acid residues, in particular D207Y;
H133all possible amino acid residues, in particular H133Y;
15 H205all possible amino acid residues, in particular H205H,
H205C, H205R;
S187all possible amino acid residues, in particular S187D;
A210all possible amino acid residues, in particular A210S,
A210T;
20 H405all possible amino acid residues, in particular H405D;
K176all possible amino acid residues, in particular K176R;
F279all possible amino acid residues, in particular F279Y;
Q298all possible amino acid residues, in particular Q298H;
G299all possible amino acid residues, in particular G299R;
25 L308all possible amino acid residues, in particular L308F;
T412all possible amino acid residues, in particular T412A;

Further, *B. licheniformis* alpha-amylase shown in SEQ ID NO: 4 comprising at least one of the following mutations may be used as backbone:

30 M15all possible amino acid residues;
A33all possible amino acid residues;

When using LE429 (shown in SEQ ID NO: 2) as the backbone (i.e., as the parent Termamyl-like alpha-amylase) by combining LE174 with the mutation I201F (SEQ ID NO: 4 numbering), the
35 mutations/alterations, in particular substitutions, deletions and insertions, may according to the invention be made in one or more of the following positions to improve the reduced ability

to cleave a substrate close to the branching point, and to improve substrate specificity and/or improved specific activity: W13, G48, T49, S50, Q51, A52, D53, V54, G57, G107, G108, A111, S168, M197 (using the SEQ ID NO: 4 numbering)

5 wherein (a) the alteration(s) are independently

(i) an insertion of an amino acid downstream of the amino acid which occupies the position,

(ii) a deletion of the amino acid which occupies the position, or

10 (iii) a substitution of the amino acid which occupies the position with a different amino acid,

(b) the variant has alpha-amylase activity and (c) each position corresponds to a position of the amino acid sequence of the parent Termamyl-like alpha-amylase having the amino acid sequence of SEQ ID NO: 4.

15 In a preferred embodiment a variant of the invention comprises at least one mutation in a position corresponding to the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

20 V54N, A52S, A52S+V54N, T49L, T49+G107A, A52S+V54N+T49L+G107A, A52S+V54N+T49L, G107A, Q51R, Q51R+A52S, A52N; or
T49F+G107A, T49V+G107A, T49D+G107A, T49Y+G107A, T49S+G107A, T49N+G107A, T49I+G107A, T49L+A52S+G107A, T49L+A52T+G107A, T49L+A52F+G107A, T49L+A52L+G107A, T49L+A52I+G107A,
25 T49L+A52V+G107A; or
T49V, T49I, T49D, T49N, T49S, T49Y, T49F, T49W, T49M, T49E, T49Q, T49K, T49R, A52T, A52L, A52I, A52V, A52M, A52F, A52Y, A52W, V54M, G107V, G07I, G107L, G107C.

30 In a preferred embodiment a variant of the invention comprises at least one mutation in a position corresponding to the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

W13F, L, I, V, Y, A;

G48A, V, S, T, I, L;

35 *48aD or *48aY (i.e., insertion of D or Y);

T49X;

*49aX (i.e., insertion of any amino acid residue)

S50X, in particular D,Y,L,T,V,I;

Q51R,K;

A52X, in particular A52S,N,T,F,L,I,V;

D53E,Q,Y,I,N,S,T,V,L;

5 V54X, in particular V54I,N,W,Y,F,L;

G57S,A,V,L,I,F,Y,T;

G107X, in particular G107A,V,S,T,I,L,C;

G108X, in particular G108A,V,S,T,I,L;

A111V,I,L;

10 S168Y;

M197X, in particular Y,F,L,I,T,A,G.

In a preferred embodiment a variant of the invention comprises at least one mutation in a position corresponding to the following mutations in the amino acid sequence shown in SEQ

15 ID NO: 4:

T49X+A52X+V54N/I/L/Y/F/W+G107A, and may further comprise G108A.

In a preferred embodiment a variant of the invention comprises at least one mutation in a position corresponding to the following mutations in the amino acid sequence shown in SEQ

20 ID NO: 4:

T49L+G107A;

T49I+G107A;

T49L+G107A+V54I;

T49I+G107A+V54I;

25 A52S+V54N+T49L+G107A;

A52S+V54I+T49L+G107A;

A52S+T49L+G107A;

A52T+T49L+G107A;

A52S+V54N+T49I+G107A;

30 A52S+V54I+T49I+G107A;

A52S+T49I+G107A;

T49L+G108A;

T49I+G108A;

T49L+G108A+V54I;

35 T49I+G108A+V54I.

General mutations in variants of the invention

It may be preferred that a variant of the invention comprises one or more modifications in addition to those outlined above. Thus, it may be advantageous that one or more proline residues present in the part of the alpha-amylase variant which is modified is/are replaced with a non-proline residue which may be any of the possible, naturally occurring non-proline residues, and which preferably is an alanine, glycine, serine, threonine, valine or leucine.

Analogously, it may be preferred that one or more cysteine residues present among the amino acid residues with which the parent alpha-amylase is modified is/are replaced with a non-cysteine residue such as serine, alanine, threonine, glycine, valine or leucine.

Furthermore, a variant of the invention may - either as the only modification or in combination with any of the above outlined modifications - be modified so that one or more Asp and/or Glu present in an amino acid fragment corresponding to the amino acid fragment 185-209 of SEQ ID NO. 4 is replaced by an Asn and/or Gln, respectively. Also of interest is the replacement, in the Termamyl-like alpha-amylase, of one or more of the Lys residues present in an amino acid fragment corresponding to the amino acid fragment 185-209 of SEQ ID NO: 4 by an Arg.

It will be understood that the present invention encompasses variants incorporating two or more of the above outlined modifications.

Furthermore, it may be advantageous to introduce point-mutations in any of the variants described herein.

Methods for preparing alpha-amylase variants

Several methods for introducing mutations into genes are known in the art. After a brief discussion of the cloning of alpha-amylase-encoding DNA sequences, methods for generating mutations at specific sites within the alpha-amylase-encoding sequence will be discussed.

Cloning a DNA sequence encoding an alpha-amylase

The DNA sequence encoding a parent alpha-amylase may be isolated from any cell or microorganism producing the alpha-amylase in question, using various methods well known in the art. First, a genomic DNA and/or cDNA library should be constructed using chromosomal DNA or messenger RNA from the organism that produces the alpha-amylase to be studied. Then, if the amino acid sequence of the alpha-amylase is known, homologous, labelled oligonucleotide probes may be synthesized and used to identify alpha-amylase-encoding clones from a genomic library prepared from the organism in question. Alternatively, a labelled oligonucleotide probe containing sequences homologous to a known alpha-amylase gene could be used as a probe to identify alpha-amylase-encoding clones, using hybridization and washing conditions of lower stringency.

Yet another method for identifying alpha-amylase-encoding clones would involve inserting fragments of genomic DNA into an expression vector, such as a plasmid, transforming alpha-amylase-negative bacteria with the resulting genomic DNA library, and then plating the transformed bacteria onto agar containing a substrate for alpha-amylase, thereby allowing clones expressing the alpha-amylase to be identified.

Alternatively, the DNA sequence encoding the enzyme may be prepared synthetically by established standard methods, e.g., the phosphoroamidite method described by S.L. Beaucage and M.H. Caruthers (1981) or the method described by Matthes et al. (1984). In the phosphoroamidite method, oligonucleotides are synthesized, e.g., in an automatic DNA synthesizer, purified, annealed, ligated and cloned in appropriate vectors.

Finally, the DNA sequence may be of mixed genomic and synthetic origin, mixed synthetic and cDNA origin or mixed genomic and cDNA origin, prepared by ligating fragments of synthetic, genomic or cDNA origin (as appropriate, the fragments corresponding to various parts of the entire DNA sequence), in accordance with standard techniques. The DNA sequence may also be prepared by polymerase chain reaction (PCR) using specific primers, for instance as described in US 4,683,202 or R.K. Saiki

et al. (1988).

Site-directed mutagenesis

Once an alpha-amylase-encoding DNA sequence has been
5 isolated, and desirable sites for mutation identified, mutations
may be introduced using synthetic oligonucleotides. These oligo-
nucleotides contain nucleotide sequences flanking the desired
mutation sites; mutant nucleotides are inserted during oligo-
nucleotide synthesis. In a specific method, a single-stranded
10 gap of DNA, bridging the alpha-amylase-encoding sequence, is
created in a vector carrying the alpha-amylase gene. Then the
synthetic nucleotide, bearing the desired mutation, is annealed
to a homologous portion of the single-stranded DNA. The re-
maining gap is then filled in with DNA polymerase I (Klenow
15 fragment) and the construct is ligated using T4 ligase. A
specific example of this method is described in Morinaga et al.
(1984). US 4,760,025 disclose the introduction of oligonucleoti-
des encoding multiple mutations by performing minor alterations
of the cassette. However, an even greater variety of mutations
20 can be introduced at any one time by the Morinaga method,
because a multitude of oligonucleotides, of various lengths, can
be introduced.

Another method for introducing mutations into alpha-amylase-
encoding DNA sequences is described in Nelson and Long (1989).
25 It involves the 3-step generation of a PCR fragment containing
the desired mutation introduced by using a chemically syn-
thesized DNA strand as one of the primers in the PCR reactions.
From the PCR-generated fragment, a DNA fragment carrying the
mutation may be isolated by cleavage with restriction
30 endonucleases and reinserted into an expression plasmid.

Random Mutagenesis

Random mutagenesis is suitably performed either as localised
or region-specific random mutagenesis in at least three parts of
35 the gene translating to the amino acid sequence shown in
question, or within the whole gene.

The random mutagenesis of a DNA sequence encoding a parent

alpha-amylase may be conveniently performed by use of any method known in the art.

In relation to the above, a further aspect of the present invention relates to a method for generating a variant of a parent alpha-amylase, e.g., wherein the variant exhibits a reduced capability of cleaving an oligo-saccharide substrate close to the branching point, and further exhibits improved substrate specificity and/or improved specific activity relative to the parent, the method:

- 10 (a) subjecting a DNA sequence encoding the parent alpha-amylase to random mutagenesis,
- (b) expressing the mutated DNA sequence obtained in step (a) in a host cell, and
- (c) screening for host cells expressing an alpha-amylase
- 15 variant which has an altered property (i.e., thermal stability) relative to the parent alpha-amylase.

Step (a) of the above method of the invention is preferably performed using doped primers. For instance, the random mutagenesis may be performed by use of a suitable physical or chemical mutagenizing agent, by use of a suitable

20 oligonucleotide, or by subjecting the DNA sequence to PCR generated mutagenesis. Furthermore, the random mutagenesis may be performed by use of any combination of these mutagenizing agents. The mutagenizing agent may, e.g., be one, which induces

25 transitions, transversions, inversions, scrambling, deletions, and/or insertions.

Examples of a physical or chemical mutagenizing agent suitable for the present purpose include ultraviolet (UV) ir-radiation, hydroxylamine, N-methyl-N'-nitro-N-nitrosoguanidine (MNNG), O-methyl hydroxylamine, nitrous acid, ethyl methane sulphonate (EMS), sodium bisulphite, formic acid, and nucleotide analogues.

30 When such agents are used, the mutagenesis is typically performed by incubating the DNA sequence encoding the parent enzyme to be mutagenized in the presence of the mutagenizing agent of choice under suitable conditions for the mutagenesis to

35 take place, and selecting for mutated DNA having the desired properties. When the mutagenesis is performed by the use of an

oligonucleotide, the oligonucleotide may be doped or spiked with the three non-parent nucleotides during the synthesis of the oligonucleotide at the positions, which are to be changed. The doping or spiking may be done so that codons for unwanted amino acids are avoided. The doped or spiked oligonucleotide can be incorporated into the DNA encoding the alpha-amylase enzyme by any published technique, using e.g., PCR, LCR or any DNA polymerase and ligase as deemed appropriate. Preferably, the doping is carried out using "constant random doping", in which the percentage of wild type and mutation in each position is predefined. Furthermore, the doping may be directed toward a preference for the introduction of certain nucleotides, and thereby a preference for the introduction of one or more specific amino acid residues. The doping may be made, e.g., so as to allow for the introduction of 90% wild type and 10% mutations in each position. An additional consideration in the choice of a doping scheme is based on genetic as well as protein-structural constraints. The doping scheme may be made by using the DOPE program, which, *inter alia*, ensures that introduction of stop codons is avoided. When PCR-generated mutagenesis is used, either a chemically treated or non-treated gene encoding a parent alpha-amylase is subjected to PCR under conditions that increase the mis-incorporation of nucleotides (Deshler 1992; Leung et al., Technique, Vol.1, 1989, pp. 11-15). A mutator strain of *E. coli* (Fowler et al., Molec. Gen. Genet., 133, 1974, pp. 179-191), *S. cerevisiae* or any other microbial organism may be used for the random mutagenesis of the DNA encoding the alpha-amylase by, e.g., transforming a plasmid containing the parent glycosylase into the mutator strain, growing the mutator strain with the plasmid and isolating the mutated plasmid from the mutator strain. The mutated plasmid may be subsequently transformed into the expression organism. The DNA sequence to be mutagenized may be conveniently present in a genomic or cDNA library prepared from an organism expressing the parent alpha-amylase. Alternatively, the DNA sequence may be present on a suitable vector such as a plasmid or a bacteriophage, which as such may be incubated with or

otherwise exposed to the mutagenising agent. The DNA to be mutagenized may also be present in a host cell either by being integrated in the genome of said cell or by being present on a vector harboured in the cell. Finally, the DNA to be mutagenized
5 may be in isolated form. It will be understood that the DNA sequence to be subjected to random mutagenesis is preferably a cDNA or a genomic DNA sequence. In some cases it may be convenient to amplify the mutated DNA sequence prior to performing the expression step b) or the screening step c). Such
10 amplification may be performed in accordance with methods known in the art, the presently preferred method being PCR-generated amplification using oligonucleotide primers prepared on the basis of the DNA or amino acid sequence of the parent enzyme. Subsequent to the incubation with or exposure to the
15 mutagenising agent, the mutated DNA is expressed by culturing a suitable host cell carrying the DNA sequence under conditions allowing expression to take place. The host cell used for this purpose may be one which has been transformed with the mutated DNA sequence, optionally present on a vector, or one which was
20 carried the DNA sequence encoding the parent enzyme during the mutagenesis treatment. Examples of suitable host cells are the following: gram positive bacteria such as *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus lentus*, *Bacillus brevis*, *Bacillus stearothermophilus*, *Bacillus alkalophilus*, *Bacillus*
25 *amyloliquefaciens*, *Bacillus coagulans*, *Bacillus circulans*, *Bacillus lautus*, *Bacillus megaterium*, *Bacillus thuringiensis*, *Streptomyces lividans* or *Streptomyces murinus*; and gram-negative bacteria such as *E. coli*. The mutated DNA sequence may further comprise a DNA sequence encoding functions permitting expression
30 of the mutated DNA sequence.

Localised random mutagenesis

The random mutagenesis may be advantageously localised to a part of the parent alpha-amylase in question. This may, e.g., be
5 advantageous when certain regions of the enzyme have been identified to be of particular importance for a given property of the enzyme, and when modified are expected to result in a variant having improved properties. Such regions may normally be identified when the tertiary structure of the parent enzyme has
10 been elucidated and related to the function of the enzyme.

The localised, or region-specific, random mutagenesis is conveniently performed by use of PCR generated mutagenesis techniques as described above or any other suitable technique known in the art. Alternatively, the DNA sequence encoding the
15 part of the DNA sequence to be modified may be isolated, e.g., by insertion into a suitable vector, and said part may be subsequently subjected to mutagenesis by use of any of the mutagenesis methods discussed above.

Alternative methods of providing alpha-amylase variants

Alternative methods for providing variants of the invention include gene-shuffling method known in the art including the methods e.g., described in WO 95/22625 (from Affymax Technologies N.V.) and WO 96/00343 (from Novo Nordisk A/S).

25

Expression of alpha-amylase variants

According to the invention, a DNA sequence encoding the variant produced by methods described above, or by any alternative methods known in the art, can be expressed, in enzyme form,
30 using an expression vector which typically includes control sequences encoding a promoter, operator, ribosome binding site, translation initiation signal, and, optionally, a repressor gene or various activator genes.

The recombinant expression vector carrying the DNA sequence
35 encoding an alpha-amylase variant of the invention may be any vector, which may conveniently be subjected to recombinant DNA procedures, and the choice of vector will often depend on the

host cell into which it is to be introduced. Thus, the vector may be an autonomously replicating vector, i.e., a vector, which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g., a plasmid, a bacteriophage or an extrachromosomal element, minichromosome or an artificial chromosome. Alternatively, the vector may be one which, when introduced into a host cell, is integrated into the host cell genome and replicated together with the chromosome(s) into which it has been integrated.

10 In the vector, the DNA sequence should be operably connected to a suitable promoter sequence. The promoter may be any DNA sequence, which shows transcriptional activity in the host cell of choice and may be derived from genes encoding proteins either homologous or heterologous to the host cell. Examples of
15 suitable promoters for directing the transcription of the DNA sequence encoding an alpha-amylase variant of the invention, especially in a bacterial host, are the promoter of the lac operon of *E.coli*, the *Streptomyces coelicolor* agarase gene *dagA* promoters, the promoters of the *Bacillus licheniformis* alpha-amylase gene (*amyL*), the promoters of the *Bacillus*
20 *stearothermophilus* maltogenic amylase gene (*amyM*), the promoters of the *Bacillus amyloliquefaciens* alpha-amylase (*amyQ*), the promoters of the *Bacillus subtilis* *xylA* and *xylB* genes etc. For transcription in a fungal host, examples of useful promoters are
25 those derived from the gene encoding *A. oryzae* TAKA amylase, *Rhizomucor miehei* aspartic proteinase, *A. niger* neutral alpha-amylase, *A. niger* acid stable alpha-amylase, *A. niger* glucoamylase, *Rhizomucor miehei* lipase, *A. oryzae* alkaline protease, *A. oryzae* triose phosphate isomerase or *A. nidulans*
30 acetamidase.

The expression vector of the invention may also comprise a suitable transcription terminator and, in eukaryotes, polyadenylation sequences operably connected to the DNA sequence encoding the alpha-amylase variant of the invention. Termination
35 and polyadenylation sequences may suitably be derived from the same sources as the promoter.

The vector may further comprise a DNA sequence enabling the

vector to replicate in the host cell in question. Examples of such sequences are the origins of replication of plasmids pUC19, pACYC177, pUB110, pE194, pAMB1 and pIJ702.

The vector may also comprise a selectable marker, e.g., a gene the product of which complements a defect in the host cell, such as the *dal* genes from *B. subtilis* or *B. licheniformis*, or one which confers antibiotic resistance such as ampicillin, kanamycin, chloramphenicol or tetracycline resistance. Furthermore, the vector may comprise *Aspergillus* selection markers such as *amdS*, *argB*, *niaD* and *sC*, a marker giving rise to hygromycin resistance, or the selection may be accomplished by co-transformation, e.g., as described in WO 91/17243.

While intracellular expression may be advantageous in some respects, e.g., when using certain bacteria as host cells, it is generally preferred that the expression is extracellular. In general, the *Bacillus* alpha-amylases mentioned herein comprise a pre-region permitting secretion of the expressed protease into the culture medium. If desirable, this pre-region may be replaced by a different preregion or signal sequence, conveniently accomplished by substitution of the DNA sequences encoding the respective preregions.

The procedures used to ligate the DNA construct of the invention encoding an alpha-amylase variant, the promoter, terminator and other elements, respectively, and to insert them into suitable vectors containing the information necessary for replication, are well known to persons skilled in the art (cf., for instance, Sambrook et al., Molecular Cloning: A Laboratory Manual, 2nd Ed., Cold Spring Harbor, 1989).

The cell of the invention, either comprising a DNA construct or an expression vector of the invention as defined above, is advantageously used as a host cell in the recombinant production of an alpha-amylase variant of the invention. The cell may be transformed with the DNA construct of the invention encoding the variant, conveniently by integrating the DNA construct (in one or more copies) in the host chromosome. This integration is generally considered to be an advantage as the DNA sequence is more likely to be stably maintained in the cell. Integration of

the DNA constructs into the host chromosome may be performed according to conventional methods, e.g., by homologous or heterologous recombination. Alternatively, the cell may be transformed with an expression vector as described above in connection with the different types of host cells.

The cell of the invention may be a cell of a higher organism such as a mammal or an insect, but is preferably a microbial cell, e.g., a bacterial or a fungal (including yeast) cell.

Examples of suitable bacteria are gram-positive bacteria such as *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus lentus*, *Bacillus brevis*, *Bacillus stearothermophilus*, *Bacillus alkalophilus*, *Bacillus amyloliquefaciens*, *Bacillus coagulans*, *Bacillus circulans*, *Bacillus lautus*, *Bacillus megaterium*, *Bacillus thuringiensis*, or *Streptomyces lividans* or *Streptomyces murinus*, or gramnegative bacteria such as *E.coli*. The transformation of the bacteria may, for instance, be effected by protoplast transformation or by using competent cells in a manner known *per se*.

The yeast organism may favourably be selected from a species of *Saccharomyces* or *Schizosaccharomyces*, e.g., *Saccharomyces cerevisiae*. The filamentous fungus may advantageously belong to a species of *Aspergillus*, e.g., *Aspergillus oryzae* or *Aspergillus niger*. Fungal cells may be transformed by a process involving protoplast formation and transformation of the protoplasts followed by regeneration of the cell wall in a manner known *per se*. A suitable procedure for transformation of *Aspergillus* host cells is described in EP 238 023.

In yet a further aspect, the present invention relates to a method of producing an alpha-amylase variant of the invention, which method comprises cultivating a host cell as described above under conditions conducive to the production of the variant and recovering the variant from the cells and/or culture medium.

The medium used to cultivate the cells may be any conventional medium suitable for growing the host cell in question and obtaining expression of the alpha-amylase variant of the invention. Suitable media are available from commercial suppliers or

may be prepared according to published recipes (e.g., as described in catalogues of the American Type Culture Collection).

5 The alpha-amylase variant secreted from the host cells may conveniently be recovered from the culture medium by well-known procedures, including separating the cells from the medium by centrifugation or filtration, and precipitating proteinaceous components of the medium by means of a salt such as ammonium sulphate, followed by the use of chromatographic procedures such
10 as ion exchange chromatography, affinity chromatography, or the like.

Industrial applications

The alpha-amylase variants of this invention possess
15 valuable properties allowing for a variety of industrial applications. In particular, enzyme variants of the invention are applicable as a component in washing, dishwashing and hard surface cleaning detergent compositions. Numerous variants are particularly useful in the production of sweeteners and ethanol,
20 e.g., fuel, drinking or industrial ethanol, from starch, and/or for textile desizing. Conditions for conventional starch-conversion processes, including starch liquefaction and/or saccharification processes, are described in, e.g., US 3,912,590 and in EP patent publications Nos. 252 730 and 63 909.

25

Production of sweeteners from starch:

A "traditional" process for conversion of starch to fructose syrups normally consists of three consecutive enzymatic processes, viz. a liquefaction process followed by a sacchari-
30 fication process and an isomerization process. During the liquefaction process, starch is degraded to dextrans by an alpha-amylase (e.g., Termamyl™) at pH values between 5.5 and 6.2 and at temperatures of 95-160°C for a period of approx. 2 hours. In order to ensure optimal enzyme stability under these condi-
35 tions, 1 mM of calcium is added (40 ppm free calcium ions).

After the liquefaction process the dextrans are converted into dextrose by addition of a glucoamylase (e.g., AMG™) and a

debranching enzyme, such as an isoamylase or a pullulanase (e.g., Promozyme™). Before this step the pH is reduced to a value below 4.5, maintaining the high temperature (above 95°C), and the liquefying alpha-amylase activity is denatured. The temperature is lowered to 60°C, and glucoamylase and debranching enzyme are added. The saccharification process proceeds for 24-72 hours.

After the saccharification process the pH is increased to a value in the range of 6-8, preferably pH 7.5, and the calcium is removed by ion exchange. The dextrose syrup is then converted into high fructose syrup using, e.g., an immobilized gluco-seisomerase (such as Sweetzyme™).

At least one enzymatic improvement of this process could be envisaged: Reduction of the calcium dependency of the liquefying alpha-amylase. Addition of free calcium is required to ensure adequately high stability of the alpha-amylase, but free calcium strongly inhibits the activity of the glucoseisomerase and needs to be removed, by means of an expensive unit operation, to an extent, which reduces the level of free calcium to below 3-5 ppm. Cost savings could be obtained if such an operation could be avoided and the liquefaction process could be performed without addition of free calcium ions.

To achieve that, a less calcium-dependent Termamyl-like alpha-amylase which is stable and highly active at low concentrations of free calcium (< 40 ppm) is required. Such a Termamyl-like alpha-amylase should have a pH optimum at a pH in the range of 4.5-6.5, preferably in the range of 4.5-5.5.

The invention also relates to a composition comprising a mixture of one or more variants of the invention derived from (as the parent Termamyl-like alpha-amylase) the *B. stearothermophilus* alpha-amylase having the sequence shown in SEQ ID NO: 8 and a Termamyl-like alpha-amylase derived from the *B. licheniformis* alpha-amylase having the sequence shown in SEQ ID NO: 4.

Further, the invention also relates to a composition comprising a mixture of one or more variants according the

invention derived from (as the parent Termamyl-like alpha-amylase) the *B. stearothermophilus* alpha-amylase having the sequence shown in SEQ ID NO: 8 and a hybrid alpha-amylase comprising a part of the *B. amyloliquefaciens* alpha-amylase shown in SEQ ID NO: 6 and a part of the *B. licheniformis* alpha-amylase shown in SEQ ID NO: 4. The latter mentioned hybrid Termamyl-like alpha-amylase comprises the 445 C-terminal amino acid residues of the *B. licheniformis* alpha-amylase shown in SEQ ID NO: 4 and the 37 N-terminal amino acid residues of the alpha-amylase derived from *B. amyloliquefaciens* shown in SEQ ID NO: 6. Said latter mentioned hybrid alpha-amylase may suitably comprise the following mutations: H156Y+A181T+N190F+A209V+Q264S (using the numbering in SEQ ID NO: 4) Preferably, said latter mentioned hybrid alpha-amylase may suitably comprise the following mutations: H156Y+A181T+N190F+A209V+Q264S+I201F (using the SEQ ID NO: 4 numbering). In the examples below said last-mentioned parent hybrid Termamyl-like alpha-amylase referred to as LE429 (shown in SEQ ID NO: 2) is used for preparing variants of the invention, which variants may be used in compositions of the invention.

An alpha-amylase variant of the invention or a composition of the invention may in an aspect of the invention be used for starch liquefaction, in detergent composition, such as laundry, dish wash compositions and hard surface cleaning, ethanol production, such as fuel, drinking and industrial ethanol production, desizing of textile, fabric and garments.

MATERIALS AND METHODS

Enzymes:

LE174: hybrid alpha-amylase variant:

LE174 is a hybrid Termamyl-like alpha-amylase being identical to the Termamyl sequence, i.e., the *Bacillus licheniformis* alpha-amylase shown in SEQ ID NO: 4, except that the N-terminal 35 amino acid residues (of the mature protein) has been replaced by the N-terminal 33 residues of BAN (mature protein), i.e., the *Bacillus amyloliquefaciens* alpha-amylase shown in SEQ ID NO: 6, which further have following mutations:

H156Y+A181T+N190F+A209V+Q264S (SEQ ID NO: 4).

LE429 hybrid alpha-amylase variant:

LE429 is a hybrid Termamyl-like alpha-amylase being identical
5 to the Termamyl sequence, i.e., the *Bacillus licheniformis*
alpha-amylase shown in SEQ ID NO: 4, except that the N-
terminal 35 amino acid residues (of the mature protein) has
been replaced by the N-terminal 33 residues of BAN (mature
10 protein), i.e., the *Bacillus amyloliquefaciens* alpha-amylase
shown in SEQ ID NO: 6, which further have following mutations:
H156Y+A181T+N190F+A209V+Q264S+I201F (SEQ ID NO: 4). LE429 is
shown as SEQ ID NO: 2 and was constructed by SOE-PCR (Higuchi
et al. 1988, Nucleic Acids Research 16:7351).

DextrozymeTM E: a balanced mixture of glucoamylase (AMG) and
15 pullulanase obtainable from selected strains of *Aspergillus*
niger and *Bacillus deramificans* (available from Novo Nordisk
A/S)

Fermentation and purification of alpha-amylase variants

20 A *B. subtilis* strain harbouring the relevant expression
plasmid is streaked on an LB-agar plate with 10 micro g/ml
kanamycin from -80°C stock, and grown overnight at 37°C.
The colonies are transferred to 100 ml BPX media supplemented
with 10 micro g/ml kanamycin in a 500 ml shaking flask.

25 Composition of BPX medium:

Potato starch	100	g/l
Barley flour	50	g/l
BAN 5000 SKB	0.1	g/l
Sodium caseinate	10	g/l
30 Soy Bean Meal	20	g/l
Na ₂ HPO ₄ , 12 H ₂ O	9	g/l
Pluronic TM	0.1	g/l

The culture is shaken at 37°C at 270 rpm for 5 days.

35 Cells and cell debris are removed from the fermentation
broth by centrifugation at 4500 rpm in 20-25 minutes. Afterwards
the supernatant is filtered to obtain a completely clear

solution. The filtrate is concentrated and washed on an UF-filter (10000 cut off membrane) and the buffer is changed to 20mM Acetate pH 5.5. The UF-filtrate is applied on a S-sepharose F.F. and elution is carried out by step elution with 0.2M NaCl in the same buffer. The eluate is dialysed against 10mM Tris, pH 9.0 and applied on a Q-sepharose F.F. and eluted with a linear gradient from 0-0.3M NaCl over 6 column volumes. The fractions that contain the activity (measured by the Phadebas assay) are pooled, pH was adjusted to pH 7.5 and remaining color was removed by a treatment with 0.5% W/vol. active coal in 5 minutes.

Activity determination - (KNU)

One Kilo alpha-amylase Unit (1 KNU) is the amount of enzyme which breaks down 5.26 g starch (Merck, Amylum Solubile, Erg. B 6, Batch 9947275) per hour in Novo Nordisk's standard method for determination of alpha-amylase based upon the following condition:

Substrate	soluble starch
Calcium content in solvent	0.0043 M
Reaction time	7-20 minutes
Temperature	37°C
pH	5.6

Detailed description of Novo Nordisk's analytical method (AF 9) is available on request.

Assay for Alpha-Amylase Activity

Alpha-Amylase activity is determined by a method employing Phadebas® tablets as substrate. Phadebas tablets (Phadebas® Amylase Test, supplied by Pharmacia Diagnostic) contain a cross-linked insoluble blue-coloured starch polymer, which has been mixed with bovine serum albumin and a buffer substance and tabletted.

For every single measurement one tablet is suspended in a tube containing 5 ml 50 mM Britton-Robinson buffer (50 mM acetic acid, 50 mM phosphoric acid, 50 mM boric acid, 0.1 mM CaCl_2 , pH adjusted to the value of interest with NaOH). The test is

performed in a water bath at the temperature of interest. The alpha-amylase to be tested is diluted in x ml of 50 mM Britton-Robinson buffer. 1 ml of this alpha-amylase solution is added to the 5 ml 50 mM Britton-Robinson buffer. The starch is hydrolysed
5 by the alpha-amylase giving soluble blue fragments. The absorbance of the resulting blue solution, measured spectrophotometrically at 620 nm, is a function of the alpha-amylase activity.

It is important that the measured 620 nm absorbance after 10
10 or 15 minutes of incubation (testing time) is in the range of 0.2 to 2.0 absorbance units at 620 nm. In this absorbance range there is linearity between activity and absorbance (Lambert-Beer law). The dilution of the enzyme must therefore be adjusted to fit this criterion. Under a specified set of conditions (temp.,
15 pH, reaction time, buffer conditions) 1 mg of a given alpha-amylase will hydrolyse a certain amount of substrate and a blue colour will be produced. The colour intensity is measured at 620 nm. The measured absorbance is directly proportional to the specific activity (activity/mg of pure alpha-amylase protein) of
20 the alpha-amylase in question under the given set of conditions.

Determining Specific Activity

The specific activity is determined using the Phadebas assay (Pharmacia) as activity/mg enzyme.

25

Measuring the pH activity profile (pH stability)

The variant is stored in 20 mM TRIS pH 7.5, 0.1 mM, CaCl_2 and tested at 30°C, 50 mM Britton-Robinson, 0.1 mM CaCl_2 . The pH activity is measured at pH 4.0, 4.5, 5.0, 5.5, 6.0, 7.0,
30 8.0, 9.5, 9.5, 10, and 10.5, using the Phadebas assay described above.

Determination Of AGU Activity and As AGU/mg

One Novo Amyloglucosidase Unit (AGU) is defined as the
35 amount of enzyme, which hydrolyzes 1 micromole maltose per minute at 37°C and pH 4.3. A detailed description of the

analytical method (AEL-SM-0131) is available on request from Novo Nordisk.

The activity is determined as AGU/ml by a method modified after (AEL-SM-0131) using the Glucose GOD-Perid kit from
5 Boehringer Mannheim, 124036. Standard: AMG-standard, batch 7-1195, 195 AGU/ml.

375 microL substrate (1% maltose in 50 mM Sodium acetate, pH 4.3) is incubated 5 minutes at 37°C. 25 microL enzyme diluted in sodium acetate is added. The reaction is stopped
10 after 10 minutes by adding 100 microL 0.25 M NaOH. 20 microL is transferred to a 96 well microtitre plate and 200 microL GOD-Perid solution is added. After 30 minutes at room temperature, the absorbance is measured at 650 nm and the activity calculated in AGU/ml from the AMG-standard.

15 The specific activity in AGU/mg is then calculated from the activity (AGU/ml) divided with the protein concentration (mg/ml).

EXAMPLES

EXAMPLE 1

Construction of Termamyl variants in accordance with the invention

Termamyl (*B. licheniformis* alpha-amylase SEQ ID NO: 4) is
25 expressed in *B. subtilis* from a plasmid denoted pDN1528. This plasmid contains the complete gene encoding Termamyl, *amyL*, the expression of which is directed by its own promoter. Further, the plasmid contains the origin of replication, *ori*, from plasmid pUB110 and the *cat* gene from plasmid pC194 conferring
30 resistance towards chloramphenicol. pDN1528 is shown in Fig. 9 of WO 96/23874. A specific mutagenesis vector containing

a major part of the coding region of SEQ ID NO: 3 was prepared. The important features of this vector, denoted pJeEN1, include an origin of replication derived from the pUC plasmids, the *cat*
35 gene conferring resistance towards chloramphenicol, and a frameshift-containing version of the *bla* gene, the wild type of which normally confers resistance towards ampicillin (amp^R

phenotype). This mutated version results in an amp^s phenotype. The plasmid pJeEN1 is shown in Fig. 10 of WO 96/23874, and the *E. coli* origin of replication, *ori*, *bla*, *cat*, the 5'-truncated version of the Termamyl amylase gene, and selected restriction sites are indicated on the plasmid.

Mutations are introduced in *amyL* by the method described by Deng and Nickoloff (1992, Anal. Biochem. 200, pp. 81-88) except that plasmids with the "selection primer" (primer #6616; see below) incorporated are selected based on the amp^r phenotype of transformed *E. coli* cells harboring a plasmid with a repaired *bla* gene, instead of employing the selection by restriction enzyme digestion outlined by Deng and Nickoloff. Chemicals and enzymes used for the mutagenesis were obtained from the Chameleon[®] mutagenesis kit from Stratagene (catalogue number 200509).

After verification of the DNA sequence in variant plasmids, the truncated gene, containing the desired alteration, is subcloned into pDN1528 as a *Pst*I-*Eco*RI fragment and transformed into the protease- and amylase-depleted *Bacillus subtilis* strain SHA273 (described in WO92/11357 and WO95/10603) in order to express the variant enzyme.

The Termamyl variant V54W was constructed by the use of the following mutagenesis primer (written 5' to 3', left to right):

PG GTC GTA GGC ACC GTA GCC CCA ATC CGC TTG (SEQ ID NO: 9)

The Termamyl variant A52W + V54W was constructed by the use of the following mutagenesis primer (written 5' to 3', left to right):

PG GTC GTA GGC ACC GTA GCC CCA ATC CCA TTG GCT CG (SEQ ID NO: 10)

Primer #6616 (written 5' to 3', left to right; P denotes a 5' phosphate):

P CTG TGA CTG GTG AGT ACT CAA CCA AGT C (SEQ ID NO: 11)

The Termamyl variant V54E was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGG TCG TAG GCA CCG TAG CCC TCA TCC GCT TG (SEQ ID NO: 12)

The Termamyl variant V54M was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGG TCG TAG GCA CCG TAG CCC ATA TCC GCT TG (SEQ ID NO: 13)

5 The Termamyl variant V54I was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGG TCG TAG GCA CCG TAG CCA ATA TCC GCT TG (SEQ ID NO: 14)

10 The Termamyl variants Y290E and Y290K were constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGC AGC ATG GAA CTG CTY ATG AAG AGG CAC GTC AAA C (SEQ ID NO:15)

Y represents an equal mixture of C and T. The presence of a
15 codon encoding either Glutamate or Lysine in position 290 was verified by DNA sequencing.

The Termamyl variant N190F was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

20 PCA TAG TTG CCG AAT TCA TTG GAA ACT TCC C (SEQ ID NO: 16)

The Termamyl variant N188P+N190F was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PCA TAG TTG CCG AAT TCA GGG GAA ACT TCC CAA TC (SEQ ID NO: 17)

25 The Termamyl variant H140K+H142D was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PCC GCG CCC CGG GAA ATC AAA TTT TGT CCA GGC TTT AAT TAG (SEQ ID NO: 18)

30 The Termamyl variant H156Y was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PCA AAA TGG TAC CAA TAC CAC TTA AAA TCG CTG (SEQ ID NO: 19)

The Termamyl variant A181T was constructed by the use of
35 the following mutagenesis primer (written 5'-3', left to right):

PCT TCC CAA TCC CAA GTC TTC CCT TGA AAC (SEQ ID NO: 20)

The Termamyl variant A209V was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PCTT AAT TTC TGC TAC GAC GTC AGG ATG GTC ATA ATC (SEQ ID NO: 21)

The Termamyl variant Q264S was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PCG CCC AAG TCA TTC GAC CAG TAC TCA GCT ACC GTA AAC (SEQ ID NO: 22)

The Termamyl variant S187D was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGC CGT TTT CAT TGT CGA CTT CCC AAT CCC (SEQ ID NO: 23)

The Termamyl variant DELTA(K370-G371-D372) (i.e., deleted of amino acid residues nos. 370, 371 and 372) was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGG AAT TTC GCG CTG ACT AGT CCC GTA CAT ATC CCC (SEQ ID NO: 24)

The Termamyl variant DELTA(D372-S373-Q374) was constructed by the use of the following mutagenesis primer (written 5'-3', left to right):

PGG CAG GAA TTT CGC GAC CTT TCG TCC CGT ACA TAT C (SEQ ID NO: 25)

The Termamyl variants A181T and A209V were combined to A181T+A209V by digesting the A181T containing pDN1528-like plasmid (i.e., pDN1528 containing within *amyL* the mutation resulting in the A181T alteration) and the A209V-containing pDN1528-like plasmid (i.e., pDN1528 containing within *amyL* the mutation resulting in the A209V alteration) with restriction enzyme *ClaI* which cuts the pDN1528-like plasmids twice resulting in a fragment of 1116 bp and the vector-part (i.e. contains the plasmid origin of replication) of 3850 bp. The fragment containing the A209V mutation and the vector part containing the A181T mutation were purified by QIAquick gel extraction kit (purchased from QIAGEN) after separation on an

agarose gel. The fragment and the vector were ligated and transformed into the protease and amylase depleted *Bacillus subtilis* strain referred to above. Plasmid from amy⁺ (clearing zones on starch containing agar-plates) and chloramphenicol resistant transformants were analysed for the presence of both mutations on the plasmid.

In a similar way as described above, H156Y and A209V were combined utilizing restriction endonucleases Acc65I and EcoRI, giving H156Y+A209V.

H156Y +A209V and A181T+A209V were combined into H156Y+A181T+A209V by the use of restriction endonucleases Acc65I and HindIII.

The 35 N-terminal residues of the mature part of Termamyl variant H156Y+ A181T+A209V were substituted by the 33 N-terminal residues of the *B. amyloliquefaciens* alpha-amylase (SEQ ID NO: 4) (which in the present context is termed BAN) by a SOE-PCR approach (Higuchi et al. 1988, Nucleic Acids Research 16:7351) as follows:

Primer 19364 (sequence 5'-3'): CCT CAT TCT GCA GCA GCA GCC GTA AAT GGC ACG CTG (SEQ ID NO: 26)

Primer 19362: CCA GAC GGC AGT AAT ACC GAT ATC CGA TAA ATG TTC CG (SEQ ID NO: 27)

Primer 19363: CGG ATA TCG GTA TTA CTG CCG TCT GGA TTC (SEQ ID NO: 28)

Primer 1C: CTC GTC CCA ATC GGT TCC GTC (SEQ ID NO: 29)

A standard PCR, polymerase chain reaction, was carried out using the Pwo thermostable polymerase from Boehringer Mannheim according to the manufacturer's instructions and the temperature cyclus: 5 minutes at 94°C, 25 cycles of (94°C for 30 seconds, 50°C for 45 seconds, 72°C for 1 minute), 72°C for 10 minutes.

An approximately 130 bp fragment was amplified in a first PCR denoted PCR1 with primers 19364 and 19362 on a DNA fragment containing the gene encoding the *B. amyloliquefaciens* alpha-amylase.

An approximately 400 bp fragment was amplified in another PCR denoted PCR2 with primers 19363 and 1C on template

pDN1528.

PCR1 and PCR2 were purified from an agarose gel and used as templates in PCR3 with primers 19364 and 1C, which resulted in a fragment of approximately 520 bp. This fragment thus
5 contains one part of DNA encoding the N-terminus from BAN fused to a part of DNA encoding Termamyl from the 35th amino acid.

The 520 bp fragment was subcloned into a pDN1528-like plasmid (containing the gene encoding Termamyl variant H156Y+
10 A181T+A209V) by digestion with restriction endonucleases *Pst*I and *Sac*II, ligation and transformation of the *B. subtilis* strain as previously described. The DNA sequence between restriction sites *Pst*I and *Sac*II was verified by DNA sequencing in extracted plasmids from *amy*+ and chloramphenicol
15 resistant transformants.

The final construct containing the correct N-terminus from BAN and H156Y+ A181T+A209V was denoted BAN(1-35)+ H156Y+ A181T+A209V.

N190F was combined with BAN(1-35)+ H156Y+ A181T+A209V
20 giving BAN(1-35)+ H156Y+ A181T+N190F+A209V by carrying out mutagenesis as described above except that the sequence of *amy*L in pJeEN1 was substituted by the DNA sequence encoding Termamyl variant BAN(1-35)+ H156Y+ A181T+A209V

Q264S was combined with BAN(1-35)+ H156Y+ A181T+A209V
25 giving BAN(1-35)+ H156Y+ A181T+A209V+Q264S by carrying out mutagenesis as described above except that the sequence of *amy*L in pJeEN was substituted by the the DNA sequence encoding Termamyl variant BAN(1-35)+ H156Y+ A181T+A209V

BAN(1-35)+ H156Y+ A181T+A209V+Q264S and BAN(1-35)+ H156Y+
30 A181T+N190F+A209V were combined into BAN(1-35)+ H156Y+ A181T+N190F+A209V+Q264S utilizing restriction endonucleases *Bsa*HI (*Bsa*HI site was introduced close to the A209V mutation) and *Pst*I.

I201F was combined with BAN(1-35)+ H156Y+
35 A181T+N190F+A209V+Q264S giving BAN(1-35)+ H156Y+ A181T+N190F+A209V+Q264S+I201F (SEQ ID NO: 2) by carrying out mutagenesis as described above. The mutagenesis primer AM100

was used, introduced the I201F substitution and removed simultaneously a Cla I restriction site, which facilitates easy pin-pointing of mutants.

5 primer AM100:

5'GATGTATGCCGACTTCGATTATGACC 3' (SEQ ID NO: 30)

EXAMPLE 2

10 Construction of Termamyl-like alpha-amylase variants with an altered cleavage pattern according to the invention

The variant of the thermostable *B. licheniformis* alpha-amylase consisting comprising the 445 C-terminal amino acid residues of the *B. licheniformis* alpha-amylase shown in SEQ ID NO: 4 and the 37 N-terminal amino acid residues of the alpha-amylase derived from *B. amyloliquefaciens* shown in SEQ ID NO: 6, and further comprising the following mutations:

15 H156Y+A181T+N190F+A209V+Q264S+I201F (the construction of this variant is described in Example 1, and the amino acid sequence shown in SEQ ID NO: 2) has a reduced capability of cleaving an substrate close to the branching point.

20 In an attempt to further improve the reduced capability of cleaving an substrate close to the branching point of said alpha-amylase variant site directed mutagenesis was carried out using the Mega-primer method as described by Sarkar and Sommer, 1990 (BioTechniques 8: 404-407):

Construction of LE313: BAN/Termamyl hybrid + H156Y+A181T+N190F+ A209V+Q264S+V54N:

30 Gene specific primer 27274 and mutagenic primer AM115 are used to amplify by PCR an approximately 440 bp DNA fragment from a pDN1528-like plasmid (harbouring the BAN(1-35)+H156Y+A181T+N190F+I201F+A209V+Q264S mutations in the gene encoding the amylase from SEQ ID NO: 4).

35 The 440 bp fragment is purified from an agarose gel and used as a Mega-primer together with primer 113711 in a second PCR carried out on the same template.

The resulting approximately 630 bp fragment is digested

with restriction enzymes EcoR V and Acc65 I and the resulting approximately 370 bp DNA fragment is purified and ligated with the pDN1528-like plasmid digested with the same enzymes. Competent *Bacillus subtilis* SHA273 (amylase and protease low) cells are transformed with the ligation and Chloramphenicol resistant transformants are checked by DNA sequencing to verify the presence of the correct mutations on the plasmid.

Primer 27274:

10 5' CATAGTTGCCGAATTCATTGGAAACTTCCC 3' (SEQ ID NO: 31)

Primer 1B:

5' CCGATTGCTGACGCTGTTATTTGC 3' (SEQ ID NO: 32)

15 primer AM115:

5' GCCAAGCGGATAACGGCTACGGTGC 3' (SEQ ID NO:33)

Construction of LE314: BAN/Termamyl hybrid + H156Y+A181T+N190F+ A209V+Q264S + A52S is carried out in a similar way, except that mutagenic primer AM116 is used.

AM116:

5' GAACGAGCCAATCGGACGTGGGCTACGG 3' (SEQ ID NO: 34)

25 Construction of LE315: BAN/Termamyl hybrid + H156Y+A181T+N190F+ A209V+Q264S + A52S+V54N is carried out in a similar way, except that mutagenic primer AM117 is used.

AM117:

30 5' GGAACGAGCCAATCGGATAACGGCTACGGTGC 3' (SEQ ID NO: 35)

Construction of LE316: BAN/Termamyl hybrid + H156Y+A181T+N190F+ A209V+Q264S + T49L is carried out in a similar way, except that mutagenic primer AM118 is used.

35

AM118:

5' GCATATAAGGGACTGAGCCAAGCGG 3' (SEQ ID NO: 36)

Construction LE317: BAN/Termamyl hybrid + H156Y+A181T+N190F+
A209V+Q264S + T49L+G107A is carried out in a similar way,
except that mutagenic primer AM118 and mutagenic primer AM119
5 are used simultaneously.

AM119:

5' CAACCACAAAGCCGCGCTGATGCG 3' (SEQ ID NO: 37)

10 Construction of LE318: BAN/Termamyl hybrid +
H156Y+A181T+N190F+ A209V+Q264S + A52S+V54N+T49L+G107A is
carried out in a similar way, except that mutagenic primer
AM120 and mutagenic primer AM119 are used simultaneously.

15 AM120:

5' GCATATAAGGGACTGAGCCAATCGGATAACGGCTACGGTGC 3' (SEQ ID NO:
38)

Construction of LE 319: BAN/Termamyl hybrid +
20 H156Y+A181T+N190F+ A209V+Q264S + A52S+V54N+T49L is carried out
in a similar way, except that mutagenic primer AM120 is used.

Construction of LE320: BAN/Termamyl hybrid +
H156Y+A181T+N190F+ A209V+Q264S + G107A is carried out in a
similar way, except that mutagenic primer AM119 is used.

25 Construction of LE322: BAN/Termamyl hybrid +
H156Y+A181T+N190F+A209V+Q264S + Q51R+A52S is carried out in a
similar way, except that mutagenic primer AM121 is used.

AM121:

5' GAACGAGCCGATCGGACGTGGGCTACGG 3' (SEQ ID NO:39)

30 Construction of LE323: BAN/Termamyl hybrid +
H156Y+A181T+N190F+ A209V+Q264S + A52N is carried out in a
similar way, except that mutagenic primer AM122 is used.

AM122:

5' GAACGAGCCAAAACGACGTGGGCTACGG 3' (SEQ ID NO: 40)

35

EXAMPLE 3

Testing of LE429 variants (saccharification)

The standard reaction conditions were:

Substrate concentration	30 % w/w
Temperature	60°C
Initial pH (at 60°C)	5.5
Enzyme dosage	
Glucoamylase	0.18 AGU/g DS
Pullulanase	0.06 PUN/g DS
Alpha-amylase	10 micro g enzyme/g DS

Dextrozyme™ E was used to provide glucoamylase and pullulanase activities

Substrates for saccharification were prepared by
 5 dissolving common corn starch in deionized water and adjusting
 the dry substance to approximately 30% w/w. The pH was
 adjusted to 5.5 (measured at 60°C), and aliquots of substrate
 corresponding to 10 g dry weight were transferred to blue cap
 glass flasks.

10 The flasks were then placed in a shaking water bath
 equilibrated at 60°C, and the enzymes added. The pH was
 readjusted to 5.5 where necessary. The samples were taken
 after 48 hours of saccharification; the pH was adjusted to
 about 3.0, and then heated in a boiling water bath for 15
 15 minutes to inactivate the enzymes. After cooling, the samples
 were treated with approximately 0.1 g mixed bed ion exchange
 resin (BIO-RAD 501 X8 (D)) for 30 minutes on a rotary mixer to
 remove salts and soluble N. After filtration, the
 carbohydrate composition was determined by HPLC. The following
 20 results were obtained:

The parent alpha-amylase for the variants is LE429.

Added Alpha-amylase Variants	DP ₁	DP ₂	DP ₃	SPEC. ACT. (NU/mg)
V54N	96.1	1.75	1.18	8200
A52S	95.9	1.80	1.11	18800
A52S+V54N	96.3	1.84	1.08	10000

T49L	96.3	1.77	1.11	12300
T49L+G107A	96.4	1.87	0.72	13600
A52S+V54N+T49L+G107A	80.5	2.55	0.43	10000
A52S+V54N+T49L	95.8	1.76	0.84	8400
G107A	94.4	1.89	1.04	19600
Q51R+A52S	95.9	1.77	1.27	16500
A52N	95.5	1.89	1.56	17600
LE174 (CONTROL)	95.9/ 95.8	1.87/ 1.83	1.17/ 1.35	16000

Compared with the control, the presence of an active alpha-amylase variant of the invention during liquefaction results in decreased panose levels (DP3).

5 Especially the T49L+G107A variant of LE429 and the A52S+V54N+T49L variant of LE429, respectively, result in a drastically decreased panose level (DP₃). If these alpha-amylase variants are used for starch liquefaction, it will not be necessary to inactivate the enzyme before the commencement
10 of saccharification.

Example 4

Liquefaction and saccharification of LE429 variants

The experiment in Example 3 was repeated for a number of
15 other LE429 variants under the same conditions.

The result is shown below:

Variant/sugar profile	DP1	DP2	DP3	DP4+
T49V+G107A	95.9%	1.72%	1.27%	1.11%
20 T49Y+G107A	95.3%	1.73%	1.29%	1.65%
T49N+G107A	95.7%	1.64%	1.51%	1.18%
T49L+A52S+G107A	95.7%	1.73%	0.95%	1.67%
T49L+A52T+G107A	95.8%	1.66%	1.03%	1.48%
T49L+A52F+G107A	95.7%	1.69%	1.16%	1.42%
25 T49L+A52L+G107A	95.5%	1.70%	1.40%	1.38%
T49L+A52I+G107A	95.9%	1.72%	1.31%	1.07%
T49L+A52V+G107A	94.7%	1.69%	1.16%	2.44%

T49L+A52V+G107A+A111V	94.5%	1.75%	0.72%	2.99%
LE429	94.9%	1.71%	1.85%	1.51%

Example 5

The experiment in Example 3 was repeated for a number of LE429 variants, except that the liquefaction was carried out at 95°C, pH 6.0 and the saccharification at 60°C, pH 4.5, 40 ppm CaCl₂, followed by inactivation. The variant referred to below are LE429 variant. The results found are as follows:

10

Variant/sugar profile	DP4+	DP3	DP2	DP1
T49F	1.15	0.92	1.83	96.12
T49D+G107A	0.84	1.03	1.82	96.3
T49I+G107A	0.97	0.64	1.84	96.55
15 T49L+G107A	0.96	0.81	1.82	96.42
T49L+A52S+G107A	1.37	0.75	1.88	96.01
T49L+A52T+G107A	0.87	0.81	1.8	96.52
T49L+A52F+G107A	0.98	0.83	1.87	96.31
T49V+G107A	0.65	0.8	2.13	96.43
20 T49Y+G107A	0.83	0.94	1.89	96.35
LE429	1.16	1.21	1.77	95.87

REFERENCES CITED

- Klein, C., et al., *Biochemistry* 1992, **31**, 8740-8746,
Mizuno, H., et al., *J. Mol. Biol.* (1993) **234**, 1282-1283,
5 Chang, C., et al., *J. Mol. Biol.* (1993) **229**, 235-238,
Larson, S.B., *J. Mol. Biol.* (1994) **235**, 1560-1584,
Lawson, C.L., *J. Mol. Biol.* (1994) **236**, 590-600,
Qian, M., et al., *J. Mol. Biol.* (1993) **231**, 785-799,
Brady, R.L., et al., *Acta Crystallogr. sect. B*, **47**, 527-535,
10 Swift, H.J., et al., *Acta Crystallogr. sect. B*, **47**, 535-544
A. Kadziola, Ph.D. Thesis: "An alpha-amylase from Barley and its
Complex with a Substrate Analogue Inhibitor Studied by X-ray
Crystallography", Department of Chemistry University of
Copenhagen 1993
15 MacGregor, E.A., *Food Hydrocolloids*, 1987, Vol.1, No. 5-6, p.
B. Diderichsen and L. Christiansen, Cloning of a maltogenic
amylase from *Bacillus stearothermophilus*, *FEMS Microbiol. let-*
ters: 56: pp. 53-60 (1988)
Hudson et al., *Practical Immunology*, Third edition (1989),
20 Blackwell Scientific Publications,
Sambrook et al., Molecular Cloning: A Laboratory Manual, 2nd
Ed., Cold Spring Harbor, 1989
S.L. Beaucage and M.H. Caruthers, Tetrahedron Letters **22**, 1981,
pp. 1859-1869
25 Matthes et al., The EMBO J. **3**, 1984, pp. 801-805.
R.K. Saiki et al., Science **239**, 1988, pp. 487-491.
Morinaga et al., (1984, *Biotechnology* 2:646-639)
Nelson and Long, Analytical Biochemistry **180**, 1989, pp. 147-151
Hunkapiller et al., 1984, *Nature* 310:105-111
30 R. Higuchi, B. Krummel, and R.K. Saiki (1988). A general method
of *in vitro* preparation and specific mutagenesis of DNA frag-
ments: study of protein and DNA interactions. *Nucl. Acids Res.*
16:7351-7367.
Dubnau et al., 1971, J. Mol. Biol. **56**, pp. 209-221.
35 Gryczan et al., 1978, J. Bacteriol. **134**, pp. 318-329.
S.D. Erlich, 1977, Proc. Natl. Acad. Sci. **74**, pp. 1680-1682.
Boel et al., 1990, Biochemistry **29**, pp. 6244-6249.

Sarkar and Sommer, 1990, BioTechniques 8, pp. 404-407.

CLAIMS

1. A variant of a parent Termamyl-like alpha-amylase, comprising an alteration at one or more positions selected from the group
5 of:
W13, G48, T49, S50, Q51, A52, D53, V54, G57, G107, G108, A111, S168, M197, wherein (a) the alteration(s) are independently
(i) an insertion of an amino acid downstream of the amino acid which occupies the position,
10 (ii) a deletion of the amino acid which occupies the position, or
(iii) a substitution of the amino acid which occupies the position with a different amino acid,
(b) the variant has alpha-amylase activity and (c) each position
15 corresponds to a position of the amino acid sequence of the parent Termamyl-like alpha-amylase having the amino acid sequence of SEQ ID NO: 4.

2. The variant of claims 1, comprises a mutation in a position
20 corresponding to at least one of the following mutations in the amino acid sequence shown in SEQ ID NO: 4:
V54N, A52S, A52S+V54N, T49L, T49+G107A, A52S+V54N+T49L+G107A, A52S+V54N+T49L, G107A, Q51R, Q51R+A52S, A52N; or
T49F+G107A, T49V+G107A, T49D+G107A, T49Y+G107A, T49S+G107A,
25 T49N+G107A, T49I+G107A, T49L+A52S+G107A, T49L+A52T+G107A, T49L+A52F+G107A, T49L+A52L+G107A, T49L+A52I+G107A, T49L+A52V+G107A; or
T49V, T49I, T49D, T49N, T49S, T49Y, T49F, T49W, T49M, T49E, T49Q, T49K, T49R, A52T, A52L, A52I, A52V, A52M, A52F, A52Y,
30 A52W, V54M, G107V, G07I, G107L, G107C.

3. The variant of claims 1 or 2, comprising a mutation in a position corresponding to at least one of the following mutations in the amino acid sequence shown in SEQ ID NO: 4:
35 W13F, L, I, V, Y, A;
G48A, V, S, T, I, L;
*48aD or *48aY (i.e., insertion of D or Y);

T49X;

*49aX (i.e., insertion of any amino acid residue)

S50X, in particular D,Y,L,T,V,I;

Q51R,K;

5 A52X, in particular A52S,N,T,F,L,I,V;

D53E,Q,Y,I,N,S,T,V,L;

V54X, in particular V54I,N,W,Y,F,L;

G57S,A,V,L,I,F,Y,T;

G107X, in particular G107A,V,S,T,I,L,C;

10 G108X, in particular G108A,V,S,T,I,L;

A111V,I,L;

S168Y;

M197X, in particular Y,F,L,I,T,A,G.

15

4. The variant of any of claims 1-3, comprises the following mutations corresponding to at least one of the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

T49X+A52X+V54N/I/L/Y/F/W+G107A.

20

5. The variant of claims 1-4, further comprising G108A.

6. The variant of claim 1-5, comprises the following mutations corresponding to at least one of the following mutations in the amino acid sequence shown in SEQ ID NO: 4:

25

T49L+G107A;

T49I+G107A;

T49L+G107A+V54I;

T49I+G107A+V54I;

30 A52S+V54N+T49L+G107A;

A52S+V54I+T49L+G107A;

A52S+T49L+G107A;

A52T+T49L+G107A;

A52S+V54N+T49I+G107A;

35 A52S+V54I+T49I+G107A;

A52S+T49I+G107A;

T49L+G108A;

T49I+G108A;
T49L+G108A+V54I;
T49I+G108A+V54I.

- 5 7. A variant of any of claims 1-6, wherein said variant has a reduced capability of cleaving an oligo-saccharide substrate close to the branching point as compared to the parent alpha-amylase.
- 10 8. A variant of any of claims 1-7, which further exhibits improved substrate specificity and/or improved specific activity relative to the parent Termamyl-like alpha-amylase.
- 15 9. A variant of any of claims 1-8, wherein the parent alpha-amylase is a hybrid alpha-amylase of SEQ ID NO: 4 and SEQ ID NO: 6.
- 20 10. The variant of any of claims 1-9, wherein the parent hybrid alpha-amylase is a hybrid alpha-amylase comprising the 445 C-terminal amino acid residues of the *B. licheniformis* alpha-amylase shown in SEQ ID NO: 4 and the 37 N-terminal amino acid residues of the alpha-amylase derived from *B. amyloliquefaciens* shown in SEQ ID NO: 6.
- 25 11. The variant of any of claims 1-10, wherein the parent hybrid Termamyl-like alpha-amylase further has the following mutations: H156Y+A181T+N190F+A209V+Q264S (using the numbering in SEQ ID NO: 4) or LE174.
- 30 12. The variant of any of claims 1-11, wherein the parent hybrid Termamyl-like alpha-amylase further has the following mutations: H156Y+A181T+N190F+A209V+Q264S+I201F (using the numbering of SEQ ID NO: 4) or LE429.
- 35 13. A DNA construct comprising a DNA sequence encoding an alpha-amylase variant according to any of claims 1-12.

14. A recombinant expression vector which carries a DNA construct according to claim 13.

15. A cell which is transformed with a DNA construct according to claim 13 or a vector according to claim 14.

16. A cell of claim 9, which is a microorganism, in particular a bacterium or a fungus, such as a gram positive bacterium such as *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus lentus*, *Bacillus brevis*, *Bacillus stearothermophilus*, *Bacillus alkalophilus*, *Bacillus amyloliquefaciens*, *Bacillus coagulans*, *Bacillus circulans*, *Bacillus lautus* or *Bacillus thuringiensis*.

17. A composition comprising:

- (i) a mixture of the alpha-amylase from *B. licheniformis* having the sequence shown in SEQ ID NO: 4 with one or more variants of claims 1-12 derived from (as the parent Termamyl-like alpha-amylase) the *B. stearothermophilus* alpha-amylase having the sequence shown in SEQ ID NO: 8; or
- (ii) a mixture of the alpha-amylase from *B. stearothermophilus* having the sequence shown in SEQ ID NO: 8 with one or more variants of claims 1-12 derived from one or more other parent Termamyl-like alpha-amylases; or
- (iii) a mixture of one or more variants of claim 1-12 derived from (as the parent Termamyl-like alpha-amylase) the *B. stearothermophilus* alpha-amylase having the sequence shown in SEQ ID NO: 8 with one or more variants according to the invention derived from one or more other parent Termamyl-like alpha-amylases.

30

18. A composition comprising:

- a mixture of one or more variants of claims 1-12 derived from (as the parent Termamyl-like alpha-amylase) the *B. stearothermophilus* alpha-amylase having the sequence shown in SEQ ID NO: 8 and a Termamyl-like alpha-amylase derived from the *B. licheniformis* alpha-amylase having the sequence shown in SEQ ID NO: 4.

35

19. A composition comprising:

a mixture of one or more variants of claims 1-12 derived from
(as the parent Termamyl-like alpha-amylase) the *B.*
5 *stearothermophilus* alpha-amylase having the sequence shown in
SEQ ID NO: 8 and a hybrid alpha-amylase comprising a part of the
B. amyloliquefaciens alpha-amylase shown in SEQ ID NO: 6 and a
part of the *B. licheniformis* alpha-amylase shown in SEQ ID NO:
4.

10

20. A composition comprising:

a mixture of one or more variants of claims 1-12 derived from
(as the parent Termamyl-like alpha-amylase) a hybrid alpha-
amylase comprising a part of the *B. amyloliquefaciens* alpha-
15 amylase shown in SEQ ID NO: 6 and a part of the *B. licheniformis*
alpha-amylase shown in SEQ ID NO: 4.

21. A composition of claim 20, wherein the hybrid alpha-amylase
is a hybrid alpha-amylase comprising the 445 C-terminal amino
20 acid residues of the *B. licheniformis* alpha-amylase shown in SEQ
ID NO: 4 and the 37 N-terminal amino acid residues of the alpha-
amylase derived from *B. amyloliquefaciens* shown in SEQ ID NO: 6.

22. A composition of claim 21, wherein the hybrid alpha-amylase
25 further has the following mutations:
H156Y+A181T+N190F+A209V+Q264S (using the numbering in SEQ ID NO:
4) or LE174.

23. A composition of claim 21, wherein the hybrid alpha-amylase
30 further has the following mutations:
H156Y+A181T+N190F+A209V+Q264S+I201F as shown in SEQ ID NO: 2 or
LE429.

24. A method for generating a variant of a parent Termamyl-like
35 alpha-amylase, which variant exhibits a reduced capability of
cleaving a substrate close to the branching point, and further
exhibits improved substrate specificity and/or improved

specific activity relative to the parent, the method comprising:

(a) subjecting a DNA sequence encoding the parent Termamyl-like alpha-amylase to random mutagenesis,

5 (b) expressing the mutated DNA sequence obtained in step (a) in a host cell, and

(c) screening for host cells expressing a mutated alpha-amylase which has increased stability at low pH and low calcium concentration relative to the parent alpha-amylase.

10

25. Use of an alpha-amylase variant of any of claims 1-12 or a composition of any of claims 17-23 for starch liquefaction; in detergent composition, such as laundry, dish washing and hard surface cleaning compositions; ethanol production, such as fuel,
15 drinking and industrial ethanol production; desizing of textiles, fabrics or garments.

SEQUENCE LISTING

5 <110> Novo Nordisk A/S
 <120>
 <130>
 10 <160> 40
 <170> PatentIn Ver. 2.1
 <210> 1
 15 <211> 1443
 <212> DNA
 <213> Bacillus amyloliquefaciens
 <220>
 20 <221> CDS
 <222> (1)..(1443)
 <400> 1
 25 gta aat ggc acg ctg atg cag tat ttt gaa tgg tat acg ccg aac gac 48
 Val Asn Gly Thr Leu Met Gln Tyr Phe Glu Trp Tyr Thr Pro Asn Asp
 1 5 10 15
 ggc cag cat tgg aaa cga ttg cag aat gat gcg gaa cat tta tgc gat 96
 Gly Gln His Trp Lys Arg Leu Gln Asn Asp Ala Glu His Leu Ser Asp
 30 20 25 30
 atc ggt att act gcc gtc tgg att ccc ccg gca tat aag gga acg agc 144
 Ile Gly Ile Thr Ala Val Trp Ile Pro Pro Ala Tyr Lys Gly Thr Ser
 35 35 40 45
 caa gcg gat gtg ggc tac ggt gct tac gac ctt tat gat tta ggg gag 192
 Gln Ala Asp Val Gly Tyr Gly Ala Tyr Asp Leu Tyr Asp Leu Gly Glu
 50 50 55 60
 40 ttt cat caa aaa ggg acg gtt cgg aca aag tac ggc aca aaa gga gag 240
 Phe His Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr Lys Gly Glu
 65 70 75 80
 ctg caa tct gcg atc aaa agt ctt cat tcc cgc gac att aac gtt tac 288
 Leu Gln Ser Ala Ile Lys Ser Leu His Ser Arg Asp Ile Asn Val Tyr
 85 90 95
 ggg gat gtg gtc atc aac cac aaa ggc ggc gct gat gcg acc gaa gat 336
 Gly Asp Val Val Ile Asn His Lys Gly Gly Ala Asp Ala Thr Glu Asp
 50 100 105 110
 gta acc gcg gtt gaa gtc gat ccc gct gac cgc aac cgc gta att tca 384
 Val Thr Ala Val Glu Val Asp Pro Ala Asp Arg Asn Arg Val Ile Ser
 115 120 125
 55 gga gaa cac cta att aaa gcc tgg aca cat ttt cat ttt ccg ggg cgc 432
 Gly Glu His Leu Ile Lys Ala Trp Thr His Phe His Phe Pro Gly Arg
 130 135 140
 60 ggc agc aca tac agc gat ttt aag tgg tat tgg tac cat ttt gac gga 480
 Gly Ser Thr Tyr Ser Asp Phe Lys Trp Tyr Trp Tyr His Phe Asp Gly
 145 150 155 160
 65 acc gat tgg gac gag tcc cga aag ctg aac cgc atc tat aag ttt caa 528
 Thr Asp Trp Asp Glu Ser Arg Lys Leu Asn Arg Ile Tyr Lys Phe Gln
 165 170 175

	ggg	aag	act	tgg	gat	tgg	gaa	gtt	tcc	aat	gaa	ttc	ggc	aac	tat	gat	576
	Gly	Lys	Thr	Trp	Asp	Trp	Glu	Val	Ser	Asn	Glu	Phe	Gly	Asn	Tyr	Asp	
				180					185					190			
5	tat	ttg	atg	tat	gcc	gac	ttt	gat	tat	gac	cat	cct	gat	gtc	gta	gca	624
	Tyr	Leu	Met	Tyr	Ala	Asp	Phe	Asp	Tyr	Asp	His	Pro	Asp	Val	Val	Ala	
			195					200					205				
10	gag	att	aag	aga	tgg	ggc	act	tgg	tat	gcc	aat	gaa	ctg	caa	ttg	gac	672
	Glu	Ile	Lys	Arg	Trp	Gly	Thr	Trp	Tyr	Ala	Asn	Glu	Leu	Gln	Leu	Asp	
		210					215					220					
15	ggc	ttc	cgt	ctt	gat	gct	gtc	aaa	cac	att	aaa	ttt	tct	ttt	ttg	cgg	720
	Gly	Phe	Arg	Leu	Asp	Ala	Val	Lys	His	Ile	Lys	Phe	Ser	Phe	Leu	Arg	
	225					230					235					240	
20	gat	tgg	gtt	aat	cat	gtc	agg	gaa	aaa	acg	ggg	aag	gaa	atg	ttt	acg	768
	Asp	Trp	Val	Asn	His	Val	Arg	Glu	Lys	Thr	Gly	Lys	Glu	Met	Phe	Thr	
					245					250					255		
25	gta	gct	gag	tac	tgg	tcg	aat	gac	ttg	ggc	gcg	ctg	gaa	aac	tat	ttg	816
	Val	Ala	Glu	Tyr	Trp	Ser	Asn	Asp	Leu	Gly	Ala	Leu	Glu	Asn	Tyr	Leu	
				260					265					270			
30	aac	aaa	aca	aat	ttt	aat	cat	tca	gtg	ttt	gac	gtg	ccg	ctt	cat	tat	864
	Asn	Lys	Thr	Asn	Phe	Asn	His	Ser	Val	Phe	Asp	Val	Pro	Leu	His	Tyr	
			275					280					285				
35	cag	ttc	cat	gct	gca	tcg	aca	cag	gga	ggc	ggc	tat	gat	atg	agg	aaa	912
	Gln	Phe	His	Ala	Ala	Ser	Thr	Gln	Gly	Gly	Gly	Tyr	Asp	Met	Arg	Lys	
		290					295					300					
40	ttg	ctg	aac	ggc	acg	gtc	gtt	tcc	aag	cat	ccg	ttg	aaa	tcg	gtt	aca	960
	Leu	Leu	Asn	Gly	Thr	Val	Val	Ser	Lys	His	Pro	Leu	Lys	Ser	Val	Thr	
	305					310					315					320	
45	ttt	gtc	gat	aac	cat	gat	aca	cag	ccg	ggg	caa	tcg	ctt	gag	tcg	act	1008
	Phe	Val	Asp	Asn	His	Asp	Thr	Gln	Pro	Gly	Gln	Ser	Leu	Glu	Ser	Thr	
					325					330					335		
50	gtc	caa	aca	tgg	ttt	aag	ccg	ctt	gct	tac	gct	ttt	att	ctc	aca	agg	1056
	Val	Gln	Thr	Trp	Phe	Lys	Pro	Leu	Ala	Tyr	Ala	Phe	Ile	Leu	Thr	Arg	
				340					345					350			
55	gaa	tct	gga	tac	cct	cag	gtt	ttc	tac	ggg	gat	atg	tac	ggg	acg	aaa	1104
	Glu	Ser	Gly	Tyr	Pro	Gln	Val	Phe	Tyr	Gly	Asp	Met	Tyr	Gly	Thr	Lys	
			355				360						365				
60	gga	gac	tcc	cag	cgc	gaa	att	cct	gcc	ttg	aaa	cac	aaa	att	gaa	ccg	1152
	Gly	Asp	Ser	Gln	Arg	Glu	Ile	Pro	Ala	Leu	Lys	His	Lys	Ile	Glu	Pro	
		370					375					380					
65	atc	tta	aaa	gcg	aga	aaa	cag	tat	gcg	tac	gga	gca	cag	cat	gat	tat	1200
	Ile	Leu	Lys	Ala	Arg	Lys	Gln	Tyr	Ala	Tyr	Gly	Ala	Gln	His	Asp	Tyr	
	385					390					395					400	
70	ttc	gac	cac	cat	gac	att	gtc	ggc	tgg	aca	agg	gaa	ggc	gac	agc	tcg	1248
	Phe	Asp	His	His	Asp	Ile	Val	Gly	Trp	Thr	Arg	Glu	Gly	Asp	Ser	Ser	
					405					410					415		
75	gtt	gca	aat	tca	ggc	ttg	gcg	gca	tta	ata	aca	gac	gga	ccc	ggc	ggg	1296
	Val	Ala	Asn	Ser	Gly	Leu	Ala	Ala	Leu	Ile	Thr	Asp	Gly	Pro	Gly	Gly	
				420					425					430			
80	gca	aag	cga	atg	tat	gtc	ggc	cgg	caa	aac	gcc	ggc	gag	aca	tgg	cat	1344
	Ala	Lys	Arg	Met	Tyr	Val	Gly	Gln	Gln	Asn	Ala	Gly	Glu	Thr	Trp	His	
			435				440						445				

gac att acc gga aac cgt tcg gag ccg gtt gtc atc aat tcg gaa ggc 1392
 Asp Ile Thr Gly Asn Arg Ser Glu Pro Val Val Ile Asn Ser Glu Gly
 450 455 460

5 tgg gga gag ttt cac gta aac ggc ggg tcg gtt tca att tat gtt caa 1440
 Trp Gly Glu Phe His Val Asn Gly Gly Ser Val Ser Ile Tyr Val Gln
 465 470 475 480

10 aga 1443
 Arg

<210> 2
 15 <211> 481
 <212> PRT
 <213> *Bacillus amyloliquefaciens*

<400> 2
 20 Val Asn Gly Thr Leu Met Gln Tyr Phe Glu Trp Tyr Thr Pro Asn Asp
 1 5 10 15

Gly Gln His Trp Lys Arg Leu Gln Asn Asp Ala Glu His Leu Ser Asp
 20 25 30

25 Ile Gly Ile Thr Ala Val Trp Ile Pro Pro Ala Tyr Lys Gly Thr Ser
 35 40 45

Gln Ala Asp Val Gly Tyr Gly Ala Tyr Asp Leu Tyr Asp Leu Gly Glu
 30 50 55 60

Phe His Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr Lys Gly Glu
 65 70 75 80

35 Leu Gln Ser Ala Ile Lys Ser Leu His Ser Arg Asp Ile Asn Val Tyr
 85 90 95

Gly Asp Val Val Ile Asn His Lys Gly Gly Ala Asp Ala Thr Glu Asp
 40 100 105 110

Val Thr Ala Val Glu Val Asp Pro Ala Asp Arg Asn Arg Val Ile Ser
 115 120 125

Gly Glu His Leu Ile Lys Ala Trp Thr His Phe His Phe Pro Gly Arg
 45 130 135 140

Gly Ser Thr Tyr Ser Asp Phe Lys Trp Tyr Trp Tyr His Phe Asp Gly
 145 150 155 160

50 Thr Asp Trp Asp Glu Ser Arg Lys Leu Asn Arg Ile Tyr Lys Phe Gln
 165 170 175

Gly Lys Thr Trp Asp Trp Glu Val Ser Asn Glu Phe Gly Asn Tyr Asp
 180 185 190

55 Tyr Leu Met Tyr Ala Asp Phe Asp Tyr Asp His Pro Asp Val Val Ala
 195 200 205

Glu Ile Lys Arg Trp Gly Thr Trp Tyr Ala Asn Glu Leu Gln Leu Asp
 60 210 215 220

Gly Phe Arg Leu Asp Ala Val Lys His Ile Lys Phe Ser Phe Leu Arg
 225 230 235 240

65 Asp Trp Val Asn His Val Arg Glu Lys Thr Gly Lys Glu Met Phe Thr
 245 250 255

Val Ala Glu Tyr Trp Ser Asn Asp Leu Gly Ala Leu Glu Asn Tyr Leu
 260 265 270

Asn Lys Thr Asn Phe Asn His Ser Val Phe Asp Val Pro Leu His Tyr
 5 275 280 285

Gln Phe His Ala Ala Ser Thr Gln Gly Gly Gly Tyr Asp Met Arg Lys
 290 295 300

10 Leu Leu Asn Gly Thr Val Val Ser Lys His Pro Leu Lys Ser Val Thr
 305 310 315 320

Phe Val Asp Asn His Asp Thr Gln Pro Gly Gln Ser Leu Glu Ser Thr
 15 325 330 335

Val Gln Thr Trp Phe Lys Pro Leu Ala Tyr Ala Phe Ile Leu Thr Arg
 340 345 350

20 Glu Ser Gly Tyr Pro Gln Val Phe Tyr Gly Asp Met Tyr Gly Thr Lys
 355 360 365

Gly Asp Ser Gln Arg Glu Ile Pro Ala Leu Lys His Lys Ile Glu Pro
 370 375 380

25 Ile Leu Lys Ala Arg Lys Gln Tyr Ala Tyr Gly Ala Gln His Asp Tyr
 385 390 395 400

Phe Asp His His Asp Ile Val Gly Trp Thr Arg Glu Gly Asp Ser Ser
 30 405 410 415

Val Ala Asn Ser Gly Leu Ala Ala Leu Ile Thr Asp Gly Pro Gly Gly
 420 425 430

35 Ala Lys Arg Met Tyr Val Gly Arg Gln Asn Ala Gly Glu Thr Trp His
 435 440 445

Asp Ile Thr Gly Asn Arg Ser Glu Pro Val Val Ile Asn Ser Glu Gly
 450 455 460

40 Trp Gly Glu Phe His Val Asn Gly Gly Ser Val Ser Ile Tyr Val Gln
 465 470 475 480

Arg

45

<210> 3
 <211> 1920
 50 <212> DNA
 <213> Bacillus licheniformis

<220>
 <221> CDS
 55 <222> (421)..(1872)

<400> 3
 cggaagattg gaagtacaaa aataagcaaa agattgtcaa tcatgtcatg agccatgcgg 60
 60 gagacggaaa aatogtctta atgcacgata tttatgcaac gttcgcagat gctgctgaag 120
 agattattaa aaagctgaaa gcaaaaggct atcaattggt aactgtatct cagcttgaag 180
 aagtgaagaa gcagagaggc tattgaataa atgagtagaa gcgccatatc ggcgcttttc 240
 65 ttttgaaga aaatataggg aaaatggtac ttgttaaaaa ttcggaatat ttatacaaca 300

```

tcatatgttt cacattgaaa ggggaggaga atcatgaaac aacaaaaacg gctttacgcc 360
cgattgctga cgctgttatt tgcgctcadc ttcttgcctgc ctcattctgc agcagcggcg 420
5 gca aat ctt aat ggg acg ctg atg cag tat ttt gaa tgg tac atg ccc 468
  Ala Asn Leu Asn Gly Thr Leu Met Gln Tyr Phe Glu Trp Tyr Met Pro 15
10 aat gac ggc caa cat tgg agg cgt ttg caa aac gac tcg gca tat ttg 516
  Asn Asp Gly Gln His Trp Arg Arg Leu Gln Asn Asp Ser Ala Tyr Leu 20 25 30
15 gct gaa cac ggt att act gcc gtc tgg att ccc ccg gca tat aag gga 564
  Ala Glu His Gly Ile Thr Ala Val Trp Ile Pro Pro Ala Tyr Lys Gly 35 40 45
20 acg agc caa gcg gat gtg ggc tac ggt gct tac gac ctt tat gat tta 612
  Thr Ser Gln Ala Asp Val Gly Tyr Gly Ala Tyr Asp Leu Tyr Asp Leu 50 55 60
25 ggg gag ttt cat caa aaa ggg acg gtt cgg aca aag tac ggc aca aaa 660
  Gly Glu Phe His Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr Lys 65 70 75 80
30 gga gag ctg caa tct gcg atc aaa agt ctt cat tcc cgc gac att aac 708
  Gly Glu Leu Gln Ser Ala Ile Lys Ser Leu His Ser Arg Asp Ile Asn 85 90 95
35 gtt tac ggg gat gtg gtc atc aac cac aaa ggc ggc gct gat gcg acc 756
  Val Tyr Gly Asp Val Val Ile Asn His Lys Gly Gly Ala Asp Ala Thr 100 105 110
40 gaa gat gta acc gcg gtt gaa gtc gat ccc gct gac cgc aac cgc gta 804
  Glu Asp Val Thr Ala Val Glu Val Asp Pro Ala Asp Arg Asn Arg Val 115 120 125
45 att tca gga gaa cac cta att aaa gcc tgg aca cat ttt cat ttt ccg 852
  Ile Ser Gly Glu His Leu Ile Lys Ala Trp Thr His Phe His Phe Pro 130 135 140
50 ggg cgc ggc agc aca tac agc gat ttt aaa tgg cat tgg tac cat ttt 900
  Gly Arg Gly Ser Thr Tyr Ser Asp Phe Lys Trp His Trp Tyr His Phe 145 150 155 160
55 gac gga acc gat tgg gac gag tcc cga aag ctg aac cgc atc tat aag 948
  Asp Gly Thr Asp Trp Asp Glu Ser Arg Lys Leu Asn Arg Ile Tyr Lys 165 170 175
60 ttt caa gga aag gct tgg gat tgg gaa gtt tcc aat gaa aac ggc aac 996
  Phe Gln Gly Lys Ala Trp Asp Trp Glu Val Ser Asn Glu Asn Gly Asn 180 185 190
65 tat gat tat ttg atg tat gcc gac atc gat tat gac cat cct gat gtc 1044
  Tyr Asp Tyr Leu Met Tyr Ala Asp Ile Asp Tyr Asp His Pro Asp Val 195 200 205
70 gca gca gaa att aag aga tgg ggc act tgg tat gcc aat gaa ctg caa 1092
  Ala Ala Glu Ile Lys Arg Trp Gly Thr Trp Tyr Ala Asn Glu Leu Gln 210 215 220
75 ttg gac ggt ttc cgt ctt gat gct gtc aaa cac att aaa ttt tct ttt 1140
  Leu Asp Gly Phe Arg Leu Asp Ala Val Lys His Ile Lys Phe Ser Phe 225 230 235 240
80 ttg cgg gat tgg gtt aat cat gtc agg gaa aaa acg ggg aag gaa atg 1188
  Leu Arg Asp Trp Val Asn His Val Arg Glu Lys Thr Gly Lys Glu Met 245 250 255

```

	ttt acg gta gct gaa tat tgg cag aat gac ttg ggc gcg ctg gaa aac	1236
	Phe Thr Val Ala Glu Tyr Trp Gln Asn Asp Leu Gly Ala Leu Glu Asn	
	260 265 270	
5	tat ttg aac aaa aca aat ttt aat cat tca gtg ttt gac gtg ccg ctt	1284
	Tyr Leu Asn Lys Thr Asn Phe Asn His Ser Val Phe Asp Val Pro Leu	
	275 280 285	
10	cat tat cag ttc cat gct gca tcg aca cag gga ggc ggc tat gat atg	1332
	His Tyr Gln Phe His Ala Ala Ser Thr Gln Gly Gly Gly Tyr Asp Met	
	290 295 300	
15	agg aaa ttg ctg aac ggt acg gtc gtt tcc aag cat ccg ttg aaa tcg	1380
	Arg Lys Leu Leu Asn Gly Thr Val Val Ser Lys His Pro Leu Lys Ser	
	305 310 315 320	
20	gtt aca ttt gtc gat aac cat gat aca cag ccg ggg caa tcg ctt gag	1428
	Val Thr Phe Val Asp Asn His Asp Thr Gln Pro Gly Gln Ser Leu Glu	
	325 330 335	
25	tcg act gtc caa aca tgg ttt aag ccg ctt gct tac gct ttt att ctc	1476
	Ser Thr Val Gln Thr Trp Phe Lys Pro Leu Ala Tyr Ala Phe Ile Leu	
	340 345 350	
30	aca agg gaa tct gga tac cct cag gtt ttc tac ggg gat atg tac ggg	1524
	Thr Arg Glu Ser Gly Tyr Pro Gln Val Phe Tyr Gly Asp Met Tyr Gly	
	355 360 365	
35	acg aaa gga gac tcc cag cgc gaa att cct gcc ttg aaa cac aaa att	1572
	Thr Lys Gly Asp Ser Gln Arg Glu Ile Pro Ala Leu Lys His Lys Ile	
	370 375 380	
40	gat tat ttc gac cac cat gac att gtc ggc ttg aca agg gaa ggc gac	1620
	Asp Tyr Phe Asp His His Asp Ile Val Gly Trp Thr Arg Glu Gly Asp	
	385 390 395 400	
45	gat tat ttc gac cac cat gac att gtc ggc ttg aca agg gaa ggc gac	1668
	Asp Tyr Phe Asp His His Asp Ile Val Gly Trp Thr Arg Glu Gly Asp	
	405 410 415	
50	agc tcg gtt gca aat tca ggt ttg gcg gca tta ata aca gac gga ccc	1716
	Ser Ser Val Ala Asn Ser Gly Leu Ala Ala Leu Ile Thr Asp Gly Pro	
	420 425 430	
55	ggt ggg gca aag cga atg tat gtc ggc cgg caa aac gcc ggt gag aca	1764
	Gly Gly Ala Lys Arg Met Tyr Val Gly Arg Gln Asn Ala Gly Glu Thr	
	435 440 445	
60	tggt cat gac att acc gga aac cgt tcg gag ccg gtt gtc atc aat tcg	1812
	Trp His Asp Ile Thr Gly Asn Arg Ser Glu Pro Val Val Ile Asn Ser	
	450 455 460	
65	gaa ggc tgg gga gag ttt cac gta aac ggc ggg tcg gtt tca att tat	1860
	Glu Gly Trp Gly Glu Phe His Val Asn Gly Gly Ser Val Ser Ile Tyr	
	465 470 475 480	
	gtt caa aga tag aagagcagag aggacggatt tcctgaagga aatccgtttt	1912
	Val Gln Arg	
	60	
	tttatattt	1920
	<210> 4	
	<211> 483	
	<212> PRT	
	<213> Bacillus licheniformis	

<400> 4
 Ala Asn Leu Asn Gly Thr Leu Met Gln Tyr Phe Glu Trp Tyr Met Pro
 1 5 10 15
 5 Asn Asp Gly Gln His Trp Arg Arg Leu Gln Asn Asp Ser Ala Tyr Leu
 20 25 30
 10 Ala Glu His Gly Ile Thr Ala Val Trp Ile Pro Pro Ala Tyr Lys Gly
 35 40 45
 Thr Ser Gln Ala Asp Val Gly Tyr Gly Ala Tyr Asp Leu Tyr Asp Leu
 50 55 60
 15 Gly Glu Phe His Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr Lys
 65 70 75 80
 Gly Glu Leu Gln Ser Ala Ile Lys Ser Leu His Ser Arg Asp Ile Asn
 85 90 95
 20 Val Tyr Gly Asp Val Val Ile Asn His Lys Gly Gly Ala Asp Ala Thr
 100 105 110
 Glu Asp Val Thr Ala Val Glu Val Asp Pro Ala Asp Arg Asn Arg Val
 115 120 125
 25 Ile Ser Gly Glu His Leu Ile Lys Ala Trp Thr His Phe His Phe Pro
 130 135 140
 30 Gly Arg Gly Ser Thr Tyr Ser Asp Phe Lys Trp His Trp Tyr His Phe
 145 150 155 160
 Asp Gly Thr Asp Trp Asp Glu Ser Arg Lys Leu Asn Arg Ile Tyr Lys
 165 170 175
 35 Phe Gln Gly Lys Ala Trp Asp Trp Glu Val Ser Asn Glu Asn Gly Asn
 180 185 190
 Tyr Asp Tyr Leu Met Tyr Ala Asp Ile Asp Tyr Asp His Pro Asp Val
 195 200 205
 40 Ala Ala Glu Ile Lys Arg Trp Gly Thr Trp Tyr Ala Asn Glu Leu Gln
 210 215 220
 45 Leu Asp Gly Phe Arg Leu Asp Ala Val Lys His Ile Lys Phe Ser Phe
 225 230 235 240
 Leu Arg Asp Trp Val Asn His Val Arg Glu Lys Thr Gly Lys Glu Met
 245 250 255
 50 Phe Thr Val Ala Glu Tyr Trp Gln Asn Asp Leu Gly Ala Leu Glu Asn
 260 265 270
 Tyr Leu Asn Lys Thr Asn Phe Asn His Ser Val Phe Asp Val Pro Leu
 275 280 285
 55 His Tyr Gln Phe His Ala Ala Ser Thr Gln Gly Gly Gly Tyr Asp Met
 290 295 300
 60 Arg Lys Leu Leu Asn Gly Thr Val Val Ser Lys His Pro Leu Lys Ser
 305 310 315 320
 Val Thr Phe Val Asp Asn His Asp Thr Gln Pro Gly Gln Ser Leu Glu
 325 330 335
 65 Ser Thr Val Gln Thr Trp Phe Lys Pro Leu Ala Tyr Ala Phe Ile Leu
 340 345 350

```

    Thr Arg Glu Ser Gly Tyr Pro Gln Val Phe Tyr Gly Asp Met Tyr Gly
      355                               360                               365
5   Thr Lys Gly Asp Ser Gln Arg Glu Ile Pro Ala Leu Lys His Lys Ile
      370                               375                               380

    Glu Pro Ile Leu Lys Ala Arg Lys Gln Tyr Ala Tyr Gly Ala Gln His
    385                               390                               395                               400
10  Asp Tyr Phe Asp His His Asp Ile Val Gly Trp Thr Arg Glu Gly Asp
      405                               410                               415

    Ser Ser Val Ala Asn Ser Gly Leu Ala Ala Leu Ile Thr Asp Gly Pro
    420                               425                               430
15  Gly Gly Ala Lys Arg Met Tyr Val Gly Arg Gln Asn Ala Gly Glu Thr
      435                               440                               445

    Trp His Asp Ile Thr Gly Asn Arg Ser Glu Pro Val Val Ile Asn Ser
    450                               455                               460
20  Glu Gly Trp Gly Glu Phe His Val Asn Gly Gly Ser Val Ser Ile Tyr
    465                               470                               475                               480
25  Val Gln Arg

30  <210> 5
    <211> 2604
    <212> DNA
    <213> Bacillus amyloliquefaciens

35  <220>
    <221> -10_signal
    <222> (707)..(712)

    <220>
40  <221> -35_signal
    <222> (729)..(734)

    <220>
    <221> RBS
45  <222> (759)..(762)

    <220>
    <221> sig_peptide
    <222> (770)..(862)
50  <220>
    <221> mat_peptide
    <222> (863)..(2314)

55  <220>
    <221> terminator
    <222> (2321)..(2376)

    <220>
60  <221> CDS
    <222> (863)..(2314)

    <400> 5
    aagcttcaag cgggtcaatcg gaatgtgcat ctcgcttcat acttaggttt tcacccgcat 60
65  attaagcagg cgtttttgaa ccgtgtgaca gaagctgttc gaaacccccgg cgggcggttt 120

```


	cgc	atc	ttt	aag	ttt	cgt	ggg	gaa	gga	aaa	gcg	tgg	gat	tgg	gaa	gta	1420
	Arg	Ile	Phe	Lys	Phe	Arg	Gly	Glu	Gly	Lys	Ala	Trp	Asp	Trp	Glu	Val	
					175					180					185		
5	tca	agt	gaa	aac	ggc	aac	tat	gac	tat	tta	atg	tat	gct	gat	ggt	gac	1468
	Ser	Ser	Glu	Asn	Gly	Asn	Tyr	Asp	Tyr	Leu	Met	Tyr	Ala	Asp	Val	Asp	
				190					195					200			
10	tac	gac	cac	cct	gat	gtc	gtg	gca	gag	aca	aaa	aaa	tgg	ggt	atc	tgg	1516
	Tyr	Asp	His	Pro	Asp	Val	Val	Ala	Glu	Thr	Lys	Lys	Trp	Gly	Ile	Trp	
			205					210					215				
15	tat	gcg	aat	gaa	ctg	tca	tta	gac	ggc	ttc	cgt	att	gat	gcc	gcc	aaa	1564
	Tyr	Ala	Asn	Glu	Leu	Ser	Leu	Asp	Gly	Phe	Arg	Ile	Asp	Ala	Ala	Lys	
		220					225					230					
20	cat	att	aaa	ttt	tca	ttt	ctg	cgt	gat	tgg	gtt	cag	gcg	gtc	aga	cag	1612
	His	Ile	Lys	Phe	Ser	Phe	Leu	Arg	Asp	Trp	Val	Gln	Ala	Val	Arg	Gln	
	235					240					245					250	
25	gcg	acg	gga	aaa	gaa	atg	ttt	acg	gtt	gcg	gag	tat	tgg	cag	aat	aat	1660
	Ala	Thr	Gly	Lys	Glu	Met	Phe	Thr	Val	Ala	Glu	Tyr	Trp	Gln	Asn	Asn	
					255					260					265		
30	gcc	ggg	aaa	ctc	gaa	aac	tac	ttg	aat	aaa	aca	agc	ttt	aat	caa	tcc	1708
	Ala	Gly	Lys	Leu	Glu	Asn	Tyr	Leu	Asn	Lys	Thr	Ser	Phe	Asn	Gln	Ser	
				270					275					280			
35	gtg	ttt	gat	gtt	ccg	ctt	cat	ttc	aat	tta	cag	gcg	gct	tcc	tca	caa	1756
	Val	Phe	Asp	Val	Pro	Leu	His	Phe	Asn	Leu	Gln	Ala	Ala	Ser	Ser	Gln	
			285					290					295				
40	gga	ggc	gga	tat	gat	atg	agg	cgt	ttg	ctg	gac	ggt	acc	gtt	gtg	tcc	1804
	Gly	Gly	Gly	Tyr	Asp	Met	Arg	Arg	Leu	Leu	Asp	Gly	Thr	Val	Val	Ser	
		300					305					310					
45	agg	cat	ccg	gaa	aag	gcg	gtt	aca	ttt	gtt	gaa	aat	cat	gac	aca	cag	1852
	Arg	His	Pro	Glu	Lys	Ala	Val	Thr	Phe	Val	Glu	Asn	His	Asp	Thr	Gln	
	315					320					325					330	
50	ccg	gga	cag	tca	ttg	gaa	tcg	aca	gtc	caa	act	tgg	ttt	aaa	ccg	ctt	1900
	Pro	Gly	Gln	Ser	Leu	Glu	Ser	Thr	Val	Gln	Thr	Trp	Phe	Lys	Pro	Leu	
					335					340					345		
55	gca	tac	gcc	ttt	att	ttg	aca	aga	gaa	tcc	ggt	tat	cct	cag	gtg	ttc	1948
	Ala	Tyr	Ala	Phe	Ile	Leu	Thr	Arg	Glu	Ser	Gly	Tyr	Pro	Gln	Val	Phe	
				350					355					360			
60	tat	ggg	gat	atg	tac	ggg	aca	aaa	ggg	aca	tcg	cca	aag	gaa	att	ccc	1996
	Tyr	Gly	Asp	Met	Tyr	Gly	Thr	Lys	Gly	Thr	Ser	Pro	Lys	Glu	Ile	Pro	
			365				370					375					
65	tca	ctg	aaa	gat	aat	ata	gag	ccg	att	tta	aaa	gcg	cgt	aag	gag	tac	2044
	Ser	Leu	Lys	Asp	Asn	Ile	Glu	Pro	Ile	Leu	Lys	Ala	Arg	Lys	Glu	Tyr	
		380					385					390					
70	gca	tac	ggg	ccc	cag	cac	gat	tat	att	gac	cac	ccg	gat	gtg	atc	gga	2092
	Ala	Tyr	Gly	Pro	Gln	His	Asp	Tyr	Ile	Asp	His	Pro	Asp	Val	Ile	Gly	
	395					400					405					410	
75	tgg	acg	agg	gaa	ggt	gac	agc	tcc	gcc	gcc	aaa	tca	ggt	ttg	gcc	gct	2140
	Trp	Thr	Arg	Glu	Gly	Asp	Ser	Ser	Ala	Ala	Lys	Ser	Gly	Leu	Ala	Ala	
					415					420					425		
80	tta	atc	acg	gac	gga	ccc	ggc	gga	tca	aag	cgg	atg	tat	gcc	ggc	ctg	2188
	Leu	Ile	Thr	Asp	Gly	Pro	Gly	Gly	Ser	Lys	Arg	Met	Tyr	Ala	Gly	Leu	

```

                430                435                440
aaa aat gcc ggc gag aca tgg tat gac ata acg ggc aac cgt tca gat 2236
Lys Asn Ala Gly Glu Thr Trp Tyr Asp Ile Thr Gly Asn Arg Ser Asp
5      445                450                455

act gta aaa atc gga tct gac ggc tgg gga gag ttt cat gta aac gat 2284
Thr Val Lys Ile Gly Ser Asp Gly Trp Gly Glu Phe His Val Asn Asp
      460                465                470

10  ggg tcc gtc tcc att tat gtt cag aaa taa ggtaataaaaa aaacacctcc 2334
    Gly Ser Val Ser Ile Tyr Val Gln Lys
    475                480

15  aagctgagtg cgggtatcag cttggaggtg cgtttatttt ttcagccgta tgacaaggtc 2394
    ggcattcaggt gtgacaaata cggtatgctg gctgtcatag gtgacaaatc cgggttttgc 2454
    gccgtttggc tttttcacat gtctgatttt tgtataatca acaggcacgg agccggaatc 2514
20  tttcgcttg gaaaaataag cggcgatcgt agctgcttcc aatatggatt gttcatcggg 2574
    atcgctgctt ttaatcaciaa cgtgggatcc 2604

25  <210> 6
    <211> 483
    <212> PRT
    <213> Bacillus amyloliquefaciens

30  <400> 6
    Val Asn Gly Thr Leu Met Gln Tyr Phe Glu Trp Tyr Thr Pro Asn Asp
      1      5      10      15

35  Gly Gln His Trp Lys Arg Leu Gln Asn Asp Ala Glu His Leu Ser Asp
      20      25      30

    Ile Gly Ile Thr Ala Val Trp Ile Pro Pro Ala Tyr Lys Gly Leu Ser
      35      40      45

40  Gln Ser Asp Asn Gly Tyr Gly Pro Tyr Asp Leu Tyr Asp Leu Gly Glu
      50      55      60

    Phe Gln Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr Lys Ser Glu
45  65      70      75      80

    Leu Gln Asp Ala Ile Gly Ser Leu His Ser Arg Asn Val Gln Val Tyr
      85      90      95

50  Gly Asp Val Val Leu Asn His Lys Ala Gly Ala Asp Ala Thr Glu Asp
      100      105      110

    Val Thr Ala Val Glu Val Asn Pro Ala Asn Arg Asn Gln Glu Thr Ser
      115      120      125

55  Glu Glu Tyr Gln Ile Lys Ala Trp Thr Asp Phe Arg Phe Pro Gly Arg
      130      135      140

    Gly Asn Thr Tyr Ser Asp Phe Lys Trp His Trp Tyr His Phe Asp Gly
60  145      150      155      160

    Ala Asp Trp Asp Glu Ser Arg Lys Ile Ser Arg Ile Phe Lys Phe Arg
      165      170      175

65  Gly Glu Gly Lys Ala Trp Asp Trp Glu Val Ser Ser Glu Asn Gly Asn
      180      185      190

```

Tyr Asp Tyr Leu Met Tyr Ala Asp Val Asp Tyr Asp His Pro Asp Val
 195 200 205
 5 Val Ala Glu Thr Lys Lys Trp Gly Ile Trp Tyr Ala Asn Glu Leu Ser
 210 215 220
 Leu Asp Gly Phe Arg Ile Asp Ala Ala Lys His Ile Lys Phe Ser Phe
 225 230 235 240
 10 Leu Arg Asp Trp Val Gln Ala Val Arg Gln Ala Thr Gly Lys Glu Met
 245 250 255
 Phe Thr Val Ala Glu Tyr Trp Gln Asn Asn Ala Gly Lys Leu Glu Asn
 260 265 270
 15 Tyr Leu Asn Lys Thr Ser Phe Asn Gln Ser Val Phe Asp Val Pro Leu
 275 280 285
 His Phe Asn Leu Gln Ala Ala Ser Ser Gln Gly Gly Gly Tyr Asp Met
 290 295 300
 Arg Arg Leu Leu Asp Gly Thr Val Val Ser Arg His Pro Glu Lys Ala
 305 310 315 320
 25 Val Thr Phe Val Glu Asn His Asp Thr Gln Pro Gly Gln Ser Leu Glu
 325 330 335
 Ser Thr Val Gln Thr Trp Phe Lys Pro Leu Ala Tyr Ala Phe Ile Leu
 340 345 350
 30 Thr Arg Glu Ser Gly Tyr Pro Gln Val Phe Tyr Gly Asp Met Tyr Gly
 355 360 365
 Thr Lys Gly Thr Ser Pro Lys Glu Ile Pro Ser Leu Lys Asp Asn Ile
 370 375 380
 Glu Pro Ile Leu Lys Ala Arg Lys Glu Tyr Ala Tyr Gly Pro Gln His
 385 390 395 400
 40 Asp Tyr Ile Asp His Pro Asp Val Ile Gly Trp Thr Arg Glu Gly Asp
 405 410 415
 Ser Ser Ala Ala Lys Ser Gly Leu Ala Ala Leu Ile Thr Asp Gly Pro
 420 425 430
 45 Gly Gly Ser Lys Arg Met Tyr Ala Gly Leu Lys Asn Ala Gly Glu Thr
 435 440 445
 Trp Tyr Asp Ile Thr Gly Asn Arg Ser Asp Thr Val Lys Ile Gly Ser
 450 455 460
 Asp Gly Trp Gly Glu Phe His Val Asn Asp Gly Ser Val Ser Ile Tyr
 465 470 475 480
 55 Val Gln Lys

60 <210> 7
 <211> 1548
 <212> DNA
 <213> Bacillus stearothermophilus
 65 <220>
 <221> CDS
 <222> (1) .. (1548)

	<400> 7																
	gcc	gca	ccg	ttt	aac	ggc	acc	atg	atg	cag	tat	ttt	gaa	tgg	tac	ttg	48
	Ala	Ala	Pro	Phe	Asn	Gly	Thr	Met	Met	Gln	Tyr	Phe	Glu	Trp	Tyr	Leu	
	1				5					10					15		
5	ccg	gat	gat	ggc	acg	tta	tgg	acc	aaa	gtg	gcc	aat	gaa	gcc	aac	aac	96
	Pro	Asp	Asp	Gly	Thr	Leu	Trp	Thr	Lys	Val	Ala	Asn	Glu	Ala	Asn	Asn	
				20					25					30			
10	tta	tcc	agc	ctt	ggc	atc	acc	gct	ctt	tgg	ctg	ccg	ccc	gct	tac	aaa	144
	Leu	Ser	Ser	Leu	Gly	Ile	Thr	Ala	Leu	Trp	Leu	Pro	Pro	Ala	Tyr	Lys	
			35					40					45				
15	gga	aca	agc	cgc	agc	gac	gta	ggg	tac	gga	gta	tac	gac	ttg	tat	gac	192
	Gly	Thr	Ser	Arg	Ser	Asp	Val	Gly	Tyr	Gly	Val	Tyr	Asp	Leu	Tyr	Asp	
		50				55						60					
20	ctc	ggc	gaa	ttc	aat	caa	aaa	ggg	acc	gtc	cgc	aca	aaa	tac	gga	aca	240
	Leu	Gly	Glu	Phe	Asn	Gln	Lys	Gly	Thr	Val	Arg	Thr	Lys	Tyr	Gly	Thr	
	65					70					75					80	
25	aaa	gct	caa	tat	ctt	caa	gcc	att	caa	gcc	gcc	cac	gcc	gct	gga	atg	288
	Lys	Ala	Gln	Tyr	Leu	Gln	Ala	Ile	Gln	Ala	Ala	His	Ala	Ala	Gly	Met	
					85				90						95		
30	caa	gtg	tac	gcc	gat	gtc	gtg	ttc	gac	cat	aaa	ggc	ggc	gct	gac	ggc	336
	Gln	Val	Tyr	Ala	Asp	Val	Val	Phe	Asp	His	Lys	Gly	Gly	Ala	Asp	Gly	
				100					105					110			
35	acg	gaa	tgg	gtg	gac	gcc	gtc	gaa	gtc	aat	ccg	tcc	gac	cgc	aac	caa	384
	Thr	Glu	Trp	Val	Asp	Ala	Val	Glu	Val	Asn	Pro	Ser	Asp	Arg	Asn	Gln	
			115					120					125				
40	gaa	atc	tcg	ggc	acc	tat	caa	atc	caa	gca	tgg	acg	aaa	ttt	gat	ttt	432
	Glu	Ile	Ser	Gly	Thr	Tyr	Gln	Ile	Gln	Ala	Trp	Thr	Lys	Phe	Asp	Phe	
		130					135					140					
45	ccc	ggg	cgg	ggc	aac	acc	tac	tcc	agc	ttt	aag	tgg	cgc	tgg	tac	cat	480
	Pro	Gly	Arg	Gly	Asn	Thr	Tyr	Ser	Ser	Phe	Lys	Trp	Arg	Trp	Tyr	His	
	145					150					155					160	
50	ttt	gac	ggc	gtt	gat	tgg	gac	gaa	agc	cga	aaa	ttg	agc	cgc	att	tac	528
	Phe	Asp	Gly	Val	Asp	Trp	Asp	Glu	Ser	Arg	Lys	Leu	Ser	Arg	Ile	Tyr	
				165						170					175		
55	aaa	ttc	cgc	ggc	atc	ggc	aaa	gcg	tgg	gat	tgg	gaa	gta	gac	acg	gaa	576
	Lys	Phe	Arg	Gly	Ile	Gly	Lys	Ala	Trp	Asp	Trp	Glu	Val	Asp	Thr	Glu	
				180					185					190			
60	aac	gga	aac	tat	gac	tac	tta	atg	tat	gcc	gac	ctt	gat	atg	gat	cat	624
	Asn	Gly	Asn	Tyr	Asp	Tyr	Leu	Met	Tyr	Ala	Asp	Leu	Asp	Met	Asp	His	
			195					200					205				
65	ccc	gaa	gtc	gtg	acc	gag	ctg	aaa	aac	tgg	ggg	aaa	tgg	tat	gtc	aac	672
	Pro	Glu	Val	Val	Thr	Glu	Leu	Lys	Asn	Trp	Gly	Lys	Trp	Tyr	Val	Asn	
		210					215					220					
70	aca	acg	aac	att	gat	ggg	ttc	cgg	ctt	gat	gcc	gtc	aag	cat	att	aag	720
	Thr	Thr	Asn	Ile	Asp	Gly	Phe	Arg	Leu	Asp	Ala	Val	Lys	His	Ile	Lys	
	225					230					235					240	
75	ttc	agt	ttt	ttt	cct	gat	tgg	ttg	tcg	tat	gtg	cgt	tct	cag	act	ggc	768
	Phe	Ser	Phe	Phe	Pro	Asp	Trp	Leu	Ser	Tyr	Val	Arg	Ser	Gln	Thr	Gly	
					245					250					255		
80	aag	ccg	cta	ttt	acc	gtc	ggg	gaa	tat	tgg	agc	tat	gac	atc	aac	aag	816
	Lys	Pro	Leu	Phe	Thr	Val	Gly	Glu	Tyr	Trp	Ser	Tyr	Asp	Ile	Asn	Lys	

15

<210> 8
 <211> 515
 <212> PRT
 <213> Bacillus stearothermophilus

5
 <400> 8
 Ala Ala Pro Phe Asn Gly Thr Met Met Gln Tyr Phe Glu Trp Tyr Leu
 1 5 10 15

10 Pro Asp Asp Gly Thr Leu Trp Thr Lys Val Ala Asn Glu Ala Asn Asn
 20 25 30

Leu Ser Ser Leu Gly Ile Thr Ala Leu Trp Leu Pro Pro Ala Tyr Lys
 35 40 45

15 Gly Thr Ser Arg Ser Asp Val Gly Tyr Gly Val Tyr Asp Leu Tyr Asp
 50 55 60

Leu Gly Glu Phe Asn Gln Lys Gly Thr Val Arg Thr Lys Tyr Gly Thr
 20 65 70 75 80

Lys Ala Gln Tyr Leu Gln Ala Ile Gln Ala Ala His Ala Ala Gly Met
 85 90 95

25 Gln Val Tyr Ala Asp Val Val Phe Asp His Lys Gly Gly Ala Asp Gly
 100 105 110

Thr Glu Trp Val Asp Ala Val Glu Val Asn Pro Ser Asp Arg Asn Gln
 115 120 125

30 Glu Ile Ser Gly Thr Tyr Gln Ile Gln Ala Trp Thr Lys Phe Asp Phe
 130 135 140

Pro Gly Arg Gly Asn Thr Tyr Ser Ser Phe Lys Trp Arg Trp Tyr His
 35 145 150 155 160

Phe Asp Gly Val Asp Trp Asp Glu Ser Arg Lys Leu Ser Arg Ile Tyr
 165 170 175

40 Lys Phe Arg Gly Ile Gly Lys Ala Trp Asp Trp Glu Val Asp Thr Glu
 180 185 190

Asn Gly Asn Tyr Asp Tyr Leu Met Tyr Ala Asp Leu Asp Met Asp His
 195 200 205

45 Pro Glu Val Val Thr Glu Leu Lys Asn Trp Gly Lys Trp Tyr Val Asn
 210 215 220

Thr Thr Asn Ile Asp Gly Phe Arg Leu Asp Ala Val Lys His Ile Lys
 50 225 230 235 240

Phe Ser Phe Phe Pro Asp Trp Leu Ser Tyr Val Arg Ser Gln Thr Gly
 245 250 255

55 Lys Pro Leu Phe Thr Val Gly Glu Tyr Trp Ser Tyr Asp Ile Asn Lys
 260 265 270

Leu His Asn Tyr Ile Thr Lys Thr Asp Gly Thr Met Ser Leu Phe Asp
 275 280 285

60 Ala Pro Leu His Asn Lys Phe Tyr Thr Ala Ser Lys Ser Gly Gly Ala
 290 295 300

Phe Asp Met Arg Thr Leu Met Thr Asn Thr Leu Met Lys Asp Gln Pro
 65 305 310 315 320

Thr Leu Ala Val Thr Phe Val Asp Asn His Asp Thr Glu Pro Gly Gln

16

325 330 335
 Ala Leu Gln Ser Trp Val Asp Pro Trp Phe Lys Pro Leu Ala Tyr Ala
 340 345 350
 5 Phe Ile Leu Thr Arg Gln Glu Gly Tyr Pro Cys Val Phe Tyr Gly Asp
 355 360 365
 Tyr Tyr Gly Ile Pro Gln Tyr Asn Ile Pro Ser Leu Lys Ser Lys Ile
 10 370 375 380
 Asp Pro Leu Leu Ile Ala Arg Arg Asp Tyr Ala Tyr Gly Thr Gln His
 385 390 395 400
 15 Asp Tyr Leu Asp His Ser Asp Ile Ile Gly Trp Thr Arg Glu Gly Gly
 405 410 415
 Thr Glu Lys Pro Gly Ser Gly Leu Ala Ala Leu Ile Thr Asp Gly Pro
 20 420 425 430
 Gly Gly Ser Lys Trp Met Tyr Val Gly Lys Gln His Ala Gly Lys Val
 435 440 445
 Phe Tyr Asp Leu Thr Gly Asn Arg Ser Asp Thr Val Thr Ile Asn Ser
 25 450 455 460
 Asp Gly Trp Gly Glu Phe Lys Val Asn Gly Gly Ser Val Ser Val Trp
 465 470 475 480
 30 Val Pro Arg Lys Thr Thr Val Ser Thr Ile Ala Arg Pro Ile Thr Thr
 485 490 495
 Arg Pro Trp Thr Gly Glu Phe Val Arg Trp Thr Glu Pro Arg Leu Val
 35 500 505 510
 35 Ala Trp Pro
 515
 40 <210> 9
 <211> 31
 <212> DNA
 <213> Artificial Sequence
 45 <220>
 <223> Description of Artificial Sequence: Primer
 <400> 9
 50 ggtagtaggc accgtagccc caatccgctt g 31
 <210> 10
 <211> 36
 55 <212> DNA
 <213> Artificial Sequence
 <220>
 60 <223> Description of Artificial Sequence: Primer
 <400> 10
 ggtagtaggc accgtagccc caatcccatt ggctcg 36
 65 <210> 11
 <211> 28

<212> DNA
<213> Artificial Sequence

<220>
5 <223> Description of Artificial Sequence: Primer

<400> 11
ctgtgactgg tgagtactca accaagtc 28

10 <210> 12
<211> 31
<212> DNA
<213> Artificial Sequence

15 <220>
<223> Description of Artificial Sequence: Primer

<400> 12
20 ggctcgtaggc accgtagccc tcatccgctt g 31

<210> 13
<211> 31
25 <212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

30 <400> 13
ggctcgtaggc accgtagccc atatccgctt g 31

35 <210> 14
<211> 31
<212> DNA
<213> Artificial Sequence

40 <220>
<223> Description of Artificial Sequence: Primer

<400> 14
45 ggctcgtaggc accgtagcca atatccgctt g 31

<210> 15
<211> 36
<212> DNA
50 <213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

55 <400> 15
gcagcatgga actgctyatg aagaggcacg tcaaac 36

<210> 16
60 <211> 30
<212> DNA
<213> Artificial Sequence

<220>
65 <223> Description of Artificial Sequence: Primer

<400> 16

catagttgcc gaattcattg gaaacttccc 30

5 <210> 17
<211> 34
<212> DNA
<213> Artificial Sequence

10 <220>
<223> Description of Artificial Sequence: Primer

<400> 17
catagttgcc gaattcaggg gaaacttccc aatc 34

15 <210> 18
<211> 41
<212> DNA
<213> Artificial Sequence

20 <220>
<223> Description of Artificial Sequence: Primer

25 <400> 18
ccgcgccccg ggaaatcaaa ttttgtccag gctttaatta g 41

30 <210> 19
<211> 32
<212> DNA
<213> Artificial Sequence

35 <220>
<223> Description of Artificial Sequence: Primer

<400> 19
caaaatggta ccaataccac ttaaaatcgc tg 32

40 <210> 20
<211> 29
<212> DNA
<213> Artificial Sequence

45 <220>
<223> Description of Artificial Sequence: Primer

50 <400> 20
cttcccaatc ccaagtcttc ccttgaaac 29

55 <210> 21
<211> 36
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

60 <400> 21
cttaatttct gctacgacgt caggatggtc ataatc 36

65 <210> 22
<211> 38
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

5 <400> 22
cgcccaagtc attcgaccag tactcagcta ccgtaaac 38

<210> 23
10 <211> 29
<212> DNA
<213> Artificial Sequence

<220>
15 <223> Description of Artificial Sequence: Primer

<400> 23
gccgttttca ttgtcgactt cccaatccc 29

20 <210> 24
<211> 35
<212> DNA
<213> Artificial Sequence

25 <220>
<223> Description of Artificial Sequence: Primer

<400> 24
30 ggaatttcgc gctgactagt cccgtacata tcccc 35

<210> 25
<211> 36
35 <212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

40 <400> 25
ggcaggaatt tcgcgacctt tcgtcccgtc catatc 36

45 <210> 26
<211> 36
<212> DNA
<213> Artificial Sequence

50 <220>
<223> Description of Artificial Sequence: Primer

<400> 26
55 cctcattctg cagcagcagc cgtaaattggc acgctg 36

<210> 27
<211> 38
<212> DNA
60 <213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

65 <400> 27
ccagacggca gtaataccga tatccgataa atgttccg 38

<210> 28
<211> 30
<212> DNA
5 <213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

10 <400> 28
cggatatcgg tattactgcc gtctggattc 30

<210> 29
15 <211> 21
<212> DNA
<213> Artificial Sequence

<220>
20 <223> Description of Artificial Sequence: Primer

<400> 29
ctcgtcccaa tcggttccgt c 21

25 <210> 30
<211> 26
<212> DNA
<213> Artificial Sequence

30 <220>
<223> Description of Artificial Sequence: Primer

<400> 30
35 gatgtatgcc gacttcgatt atgacc 26

<210> 31
<211> 30
40 <212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

45 <400> 31
catagttgcc gaattcattg gaaacttccc 30

50 <210> 32
<211> 24
<212> DNA
<213> Artificial Sequence

55 <220>
<223> Description of Artificial Sequence: Primer

<400> 32
60 ccgattgctg acgctgttat ttgc 24

<210> 33
<211> 25
<212> DNA
65 <213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: Primer
<400> 33
5 gccaagcgga taacggctac ggtgc 25

<210> 34
<211> 28
<212> DNA
10 <213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer
15 <400> 34
gaacgagcca atcggacgtg ggctacgg 28

<210> 35
20 <211> 32
<212> DNA
<213> Artificial Sequence

<220>
25 <223> Description of Artificial Sequence: Primer

<400> 35
ggaacgagcc aatcggataa cggctacggt gc 32

30 <210> 36
<211> 25
<212> DNA
<213> Artificial Sequence

35 <220>
<223> Description of Artificial Sequence: Primer

<400> 36
40 gcatataagg gactgagcca agcgg 25

<210> 37
<211> 25
45 <212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer
50 <400> 37
caaccacaaa gccggcgctg atgcg 25

55 <210> 38
<211> 41
<212> DNA
<213> Artificial Sequence

60 <220>
<223> Description of Artificial Sequence: Primer

<400> 38
65 gcatataagg gactgagcca atcggataac ggctacggtg c 41

<210> 39

<211> 28
<212> DNA
<213> Artificial Sequence

5 <220>
<223> Description of Artificial Sequence: Primer

10 <400> 39
gaacgagccg atcggacgtg ggctacgg 28

<210> 40
<211> 28
<212> DNA
15 <213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Primer

20 <400> 40
gaacgagcca aaacgacgtg ggctacgg 28

25

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
12 October 2000 (12.10.2000)

PCT

(10) International Publication Number
WO 00/60059 A3

(51) International Patent Classification⁷: C12N 9/28,
C11D 3/386

(21) International Application Number: PCT/DK00/00148

(22) International Filing Date: 28 March 2000 (28.03.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PA 1999 00437 30 March 1999 (30.03.1999) DK

(71) Applicant: NOVO NORDISK A/S [DK/DK]; Novo Allé,
DK-2880 Bagsværd (DK).

(72) Inventors: ANDERSEN, Carsten; Højeloft Vænge
162, DK-3500 Værløse (DK). JØRGENSEN, Christel,
Thea; Livjærggade 41, 4.th., DK-2100 Copenhagen Ø
(DK). BISGÅRD-FRANTZEN, Henrik; Elmevænget
8B, DK-2880 Bagsværd (DK). SVENDSEN, Allan;
Bakkeledet 28, DK-3460 Birkerød (DK). KJÆRULFF,
Søren; Kongsdalsvej 47, DK-2720 Vanløse (DK).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE,

DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU,
ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS,
LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ,
PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT,
TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent
(AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent
(AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU,
MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

- With international search report.
- Before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments.

(88) Date of publication of the international search report:
10 May 2001

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: ALPHA-AMYLASE VARIANTS

(57) Abstract: The invention relates to a variant of a parent Termamyl-like alpha-amylase, which variant exhibits altered proper-
ties, in particular reduced capability of cleaving a substrate close to the branching point, and improved substrate specificity and/or
improved specific activity relative to the parent alpha-amylase. The variant of the parent Termamyl-like alpha-amylase, comprised
an alternation at one or more positions selected from the group of W13, G48, T49, S50, Q51, A52, D53, V54, G57, G107, G108,
A111, S168 and M197.



WO 00/60059 A3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 00/00148

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C12N 9/28, C11D 3/386

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9741213 A1 (NOVO NORDISK A/S), 6 November 1997 (06.11.97), page 1716 - page 1736, abstract --	1,3,7,13-20, 25
X	WO 9623874 A1 (NOVO NORDISK A/S), 8 August 1996 (08.08.96), see abstract, claims --	1,7,13-20,25
X	WO 9418314 A1 (GENECOR INTERNATIONAL, INC.), 18 August 1994 (18.08.94), page 4, line 24 - page 5, line 17 --	1,3,13-20,25

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

3 January 2001

Date of mailing of the international search report

0 8. 03. 01

Name and mailing address of the International Searching Authority
European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk
Tel(+31-70)340-2040, Tx 31 651 epo nl,
Fax(+31-70)340-3016

Authorized officer

HAMPUS RYSTEDT/GH
Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 00/00148

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9100353 A2 (GIST-BROCADES N.V.), 10 January 1991 (10.01.91), see page 12 and claims -- -----	1,13-20,25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK00/00148

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 7
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see extra sheet *
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see extra sheet **

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.: **1-23,25, all partially.**
See also Box I.2
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☒ No protest accompanied the payment of additional search fees.

Box I.2

*

In response to the invitation to pay additional fees, the applicant has requested the search to be performed on the basis of claim 7. The enzymes according to this claim are characterized by two features:

i) they comprise at least one of the mutations mentioned in claim 1, and

ii) they have a reduced capability of cleaving an oligosaccharide substrate close to the branching point.

It is not possible to make an exhaustive search on feature ii) since this feature may well be present in previously described mutated amylases without being expressly mentioned. Feature i) does not serve to limit the scope of the search since the numbering of amino acids (and therefore also mutations) differ in the prior art. Due to the very extensive literature on mutated amylases it is not possible to translate every mutation to the numbering used in the present application.

Consequently, the search has been limited to amylases described using the same numbering of amino acids (and hence also mutations) and with either expressly mentioned reduced capability of cleaving the substrate close to a branching point or a specified mutation in position 13 (see also Box II).

Box II

The application relates to 561 Inventions.

Invention 1 to 560:

Claim 1 describes mutations at 14 different positions of alpha-amylase. Each mutation can be an insertion of an amino acid at the downstream position (20 possibilities), a deletion (1 possibility) or an amino acid exchange (19 possibilities), i.e. there are 40 possibilities in each of the 14 positions resulting in 560 possible mutations.

Invention 561:

Claim 24 relates to a method for producing mutated alpha-amylase.

S/ 74931

INTERNATIONAL SEARCH REPORT
Information on patent family members

04/12/00

International application No.

PCT/DK 00/00148

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
WO	9100353	A2	10/01/91	AT	166922 T	15/06/98
				AU	638263 B	24/06/93
				AU	5953890 A	17/01/91
				BG	61081 B	31/10/96
				BR	9006818 A	06/08/91
				CA	2030554 A	30/12/90
				CN	1050220 A	27/03/91
				DD	301620 A	29/04/93
				DE	69032360 D,T	03/12/98
				DK	410498 T	22/03/99
				EP	0410498 A,B	30/01/91
				ES	2117625 T	16/08/98
				FI	103285 B	00/00/00
				FI	910907 D	00/00/00
				JP	3086249 B	11/09/00
				JP	4500756 T	13/02/92
				KR	165550 B	15/01/99
				PT	94560 A,B	08/02/91
				US	5364782 A	15/11/94
